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# Cathodic Protection of Steel Water Tanks

*By Earl E. Norman*

DURING the past few years there has been a great deal of interest shown in what appears to many to be a new process of electrically controlling corrosion in water tanks. In order to prevent any misunderstanding, it might be well to set forth certain definitions. The title of the paper is "Cathodic Protection of Steel Water Tanks." The word "cathodic" refers to or is related to the word "cathode," which is a fundamental part of an electric cell. In fact, the writer believes this treatise can better be understood if the tank and associated parts described are considered as a large electric cell. A cathode is defined in electro-chemistry as a pole or electrode in an electrical cell, or battery, toward which the electricity flows through the liquid in the cell or through the electrolyte. It is the electrode by which electricity leaves the electrolyte. In this case the cathode is the tank body itself, and of course it is this cathode that it is desired to protect.

The word "protection" immediately gives rise to the question, "Protection against what?" The answer is protection against corrosion.

It then becomes necessary to define corrosion. A great deal of space could be devoted to this one subject. U. R. Evans in *The*

A paper presented on April 25, 1940, at the Kansas City Convention by Earl E. Norman, General Superintendent, City Water Dept., Kalamazoo, Mich.

*Corrosion of Metals* has given a definition of corrosion which uses very few words and is quite to the point. He says that while the study of metallurgy is the study of "making of metals," a study of corrosion is a study of the "unmaking of metals."

In the title of this paper there is the term "water tanks." Of course, it is well known what a water tank is. Nevertheless in order to narrow this paper down to its precise application, it requires definition. A water tank for the purpose of this paper is a steel tank; tanks of concrete and non-ferrous metals are not to be considered.

Much time could be spent in going into the theories of corrosion. These theories, involving as they do not only Ohm's Law, Faraday's Law and electrolysis, but also atoms, ions, electrons and a lot of other "ons," are liable to get one into "deep water," particularly one whose knowledge on some of these subjects is as limited as the writer's. It is believed that the greater interest is in exactly what happens. Therefore, the theory is to be disregarded in favor of discussing the problem of what happens in actual practice.

## Practices Based Upon the Theory

Everyone is more or less familiar with ordinary electroplating processes. For example, in the case of copper plating, an article is placed in a copper sulfate solution and an electrode (the anode) is also placed in the solution. A direct current enters the cell by means of the anode and passes through the copper sulfate solution onto the article which is to be plated. Copper is thus "plated" on the cathode of the cell.

Another example is familiar to anyone who has ever operated a water system in a city blessed with street cars. It is, of course, recognized that the destruction of water mains by electrolysis occurs only at points at which electricity *leaves* the main. At such points the water main is an anode. On the other hand, at places where the electric current enters the mains no damage is done.

These two very familiar examples are given simply as re-introduction to the process which is to be discussed in this paper.

## General Applications

Although one would think by the large number of inquiries on the subject of cathodic protection of water tanks that it must be a new invention, such is not really the case. The same basic idea has

been used on pipe lines for several years, the first application in the U. S. having been made in about 1915.

While there are many installations of pipe lines protected by the cathodic method of corrosion control, the few to be mentioned here will serve as examples. An oil company had a two-mile stretch of main in the Los Angeles Harbor District that averaged two leaks per month. Cathodic corrosion control was installed in 1931. Two leaks occurred within the next month but *no leaks whatever* occurred from that first month to April 16, 1940.

The Southern Counties Gas Company installed cathodic corrosion control on an 80-mile pipe line from Huntington Beach Oil Fields to San Diego in 1934. Since then the company has installed this same method of control on additional lines, now totalling 217 miles. Included in the project are 22 miles of main laid under pavements in city streets. According to information leaks have been almost entirely eliminated by the installation.

Another pipe line of interest is one in Louisiana, also about 80 miles long. This was a line previously installed and equipped with cathodic control in 1935. A five-mile section of the line was subjected to special study for purposes of determining the effectiveness of electrical protection. On this section during the six months immediately preceding the application of the protection an average of 5.5 leaks per mile per year developed. It was not anticipated that the application of cathodic corrosion control would immediately reduce the leaks. In fact, it was thought that perhaps the number of leaks might actually increase. This was found to be the case, for during the six months immediately following the application of the control, an average of 8.8 leaks per mile per year developed. The theory is that some of the accumulations of rust from the pits, which were already badly developed, was removed, so weakening the pipe wall that additional leaks were discovered. During the next twelve months however the average number of leaks dropped to 0.2 leaks per mile per year. After the system had become thoroughly established and in operation beyond any question of doubt, the protection was shut off to see what would happen. During this first six months, it was expected that the number of leaks would not be serious. This was found to be the case because only an average of 0.8 leaks per mile per year developed. During the next six months however 10 leaks per mile per year developed. The cathodic corrosion control was, therefore, placed back in operation immedi-

ately and in a manner previously described, the leaks tapered off to practically zero.

Another interesting installation is the application of cathodic corrosion control to the pipe lines of Treasure Island at the World's Fair in San Francisco. This installation is described by Lee (Jour. A. W. W. A. **32:** 319 (1940)). These pipe lines are laid through "made" ground, which is extremely corrosive. The first failure occurred 90 days after the pipe was placed in service. During the next seven weeks 48 failures occurred. Thereupon cathodic control was applied to all underground pipe structures on Treasure Island with results quite comparable to those indicated previously for the pipe line in Louisiana. The World's Fair authorities estimated that if no cathodic control had been applied, 518 leaks would have developed during the 30 weeks of construction previous to opening the Fair, rather than the actual number 146, and most of these 146 leaks occurred before the application of the control process.

## Application to Tanks

The application of cathodic corrosion control to tanks is in theory quite like the application of cathodic control to pipe lines, except that in the case of tanks the aim is to protect the container against internal corrosion, that is, corrosion from the water itself, while in the case of the pipe lines the aim is to protect the container against external corrosion. The application of the process should, therefore, be a much more simple process as applied to tanks.

Although it has been indicated that theory, as such, would be disregarded, it would be well to reconsider very briefly just a little of the theory involved in the application of this method of control of corrosion in tanks. If a cell consisting of a suitable anode in water, is set up in a tank, and if direct current of a suitable voltage and current from the source of supply is then circulated into the anode, thence to the water and to the tank, a plating action will take place quite similar to that described previously, relative to electro-plating processes. Instead of plating out copper, silver or some other metal, however, in this case hydrogen gas, or ionic hydrogen, will plate out onto the surface of the cathode or the tank. Calcium and other positive ions (depending upon the mineral content of the water) will also plate out against the surface of the tank in the same manner. As long as this process is kept up, and as long as the film of hydrogen,

calcium, etc. remains unbroken, rusting and other forms of corrosion on the tank surface will not take place.

It is therefore only necessary to provide the equipment to keep this process in operation. In practice this consists of one or more electrodes of a suitable material (usually either stainless steel or graphite) suspended from the roof of the tank into the water but insulated from the tank. These are the anodes. There is also provided a source of electric current supply. This usually consists of a transformer, a dry type of rectifier and suitable controls so that the voltage and current can be adjusted to the needs of the particular installation.

These devices are connected so that direct current from the rectifier runs from the rectifier to the anode through the water onto the tank, and thence back to the rectifier.

No matter how unique or interesting a piece of apparatus might be, it can hardly be justified unless economy is shown by its use. If capital investment is necessary, the fixed charges incurred by such capital investment must be considered. If operating costs are incurred these must also be considered. In the case of cathodic corrosion control both of these costs are incurred. The capital investment, however, is not repeated year after year, but strangely enough in many cases the capital cost of cathodic control equipment is less than a single paint job. The operation costs are also nominal. The equipment consumes so little power each month that in many cases the power cost is within the minimum charge for the use of electric service.

In the case of a 350,000-gallon tank the cost of painting the interior of the tank below the water line would have been $700 while the capital cost of installing cathodic protection was only about $400. In like manner a certain 750,000-gallon tank was equipped with control equipment at a cost of a little over $400 whereas the cost of painting the inside surface of that tank below the water line would have been $950. In the case of the latter tank, the assumption that a paint job would last five years, would make the cost of paint $190 per year. Assuming a fixed charge to cover taxes, depreciation and maintenance on the cathodic control unit of 15 per cent, the fixed charge amounts to $60 per year to which must be added the charge for electric service amounting to $12 per year, or a total cost of $72 per year. This leaves an annual saving of $118 per year or 29.5 per cent on the investment.

This financial saving is not the only advantage however. It should also be kept in mind that: (1) the tank is being prevented from disintegrating, which after all is even more important than the financial savings; and (2), it becomes unnecessary to take the tank out of service for periodic painting, a procedure which must be carried out during the warmer months, when the tank is most needed in service.

## Conclusion

In conclusion, it must be pointed out that cathodic protection is not new. It is a very old principle. In fact it is very strange, in the writer's opinion, that it was not applied many years ago. There are however, approximately 600 water tanks in the United States at the present time to which this treatment has been applied.

Replies to a questionnaire circulated by the Pittsburgh-Des Moines Steel Company indicate an overwhelming majority of opinion in favor of cathodic corrosion control. Replying to the question: "Does the electric rust prevention device protect the tank interior as well as paint or other coating material?"—68 per cent said, "Yes"; 17 per cent did not answer the question; 8 per cent could not say; but *nobody replied in the negative.* In response to the question: "If you were building a new water tank, would you specify that the paint be omitted on the interior below the water line?"—75 per cent replied "Yes"; 25 per cent did not answer the question; but, again, *nobody replied in the negative.* This questionnaire revealed that the original capital cost of the equipment ranged from $198 to $525, while the annual maintenance cost ranged from $3 per year to $25 per year.

There is no question but what the water works industry has been presented a very useful and economical device. There is no question as to its economy and if the electrodes are mounted in such a manner as to preclude difficulty from freezing, it is the writer's opinion that this device should receive the wholehearted support of the water works industry.

# Steel Tank Corrosion Prevention

*By W. C. Mabee*

UNTIL very recently the loss of metal due to rusting of water storage tank interiors has been controlled with paints, asphaltums, tar products, and metallizing coatings, the most commonly used protection agent being paint. Today paint is still used on the exterior surfaces of tanks and the interior surfaces not in contact with water but the old inner coatings may be replaced by a new application of the old principle of electric corrosion prevention devices known as "cathodic protection." The coatings, applied to water tank interiors, are seldom if ever entirely satisfactory in preventing corrosion and any device that will eliminate expensive and oft-repeated painting will prove a blessing to every water works operator who has the problem to contend with.

The principle of cathodic protection as applied to pressure vessels and steel pipe lines is relatively old, having been tried successfully for the protection of steel pipe oil lines and oil tanks in the South and Southwest nine years ago. Application of the Kirkaldy Electrolytic Systems to boilers, heaters and similar pressure vessels is at least ten years old, and some cathodic protection patents antedated the Kirkaldy ones. The same principle with some modifications is now being extensively applied to the interior of steel water tanks, and in the application the manufacturer will guarantee to prevent rust, corrosion and pitting inside your steel water tank.

Ohio was the proving grounds for these devices beginning in and around Dayton in August, 1936, where it was first applied to a 900,000 gallon standpipe. Two years later there were more than forty units operating in Ohio.

A paper presented on April 5, 1940, at the Indiana Section Meeting at Lafayette, Ind., by W. C. Mabee, Chief Engineer, Indianapolis Water Co., Indianapolis.

It was not until May, 1938 that the Indianapolis Water Company investigated electric corrosion-prevention applied to the interior of steel water tanks at a time when the 1,500,000 gallon tank in Irvington was due for an interior painting. Studies disclosed that the device could be installed for less than half the cost of painting in the first instance and that its application to tanks in Ohio was apparently proving satisfactory. With this assurance, the first installation in Indianapolis was made in the fall of 1938. A year later, electric corrosion-prevention devices were stiputated for the second 1,500,000 gallon elevated storage tank then under construction and provision made in the specifications to omit the painting of the tank interior below the water line.

It is too early to express an opinion on the performance of either installation because too few inspections have been made since placing the devices in service. After six months' exposure the first tank was drained and examined. Hard rust scale previously formed had softened and the results appeared promising.

## Tests and Observations

To test still further the efficacy of the treatment, duplicate metal tabs were suspended in the water and removed at intervals of three months for observation. It was found that those tabs that were insulated had accumulated a plating of rust whereas the tabs that were connected electrically to the tank plates were practically free of rust. Unfortunately, the tabs remaining were lost in ice movement during the winter and no further observations could be made. A recent observation of the second tank access pipe which passes through the water showed no signs of rust on the unpainted portion examined after nearly eight months' exposure.

Because of the relatively long intervals of time that elapse between drainings it is planned to continue the experiment with metal tabs in each tank, removing them frequently for observation.

When negotiating for the first installation at Indianapolis the question of the effect of ice was considered. The background of experience was meagre but it was anticipated that the steel electrodes were more or less likely to freeze solid at the surface with the possibility of injury to the tank roof from which the electrodes were suspended, when the ice fell away. Therefore, a suspension cable was provided with a limited strength and a coil provided that would permit the electrode to be retrieved.

Actually, these electrodes did get caught in the ice last winter but the action was reversed—they were frozen in when the water level was low and were pushed up against the roof members and bent. The contact short-circuited the system. In cold climates, with water subject to freezing, provision should be made, if possible, to prevent the electrodes from being held in the ice.

### Heating Elements for Protection Against Ice

Later, when the second tank was equipped, a heating element was built into each of the electrodes. Since this tank did not freeze to any extent, however, the effectiveness of the anti-freeze device has not yet been fully demonstrated. This is a problem for the manufacturer to solve.

Cathodic protection has been applied to more than 300 water tanks by one manufacturer, some of them in extremely cold climates, with interruption of service from ice trouble reported from only four or five this winter. Installations have been made by the same manufacturer in nearly every state east of Colorado, the largest number being in Ohio, Pennsylvania, Michigan, Indiana, Wisconsin, Texas and New York. The manufacturers of the equipment report that only favorable comments are being received from customers.

It may reasonably be concluded that electric corrosion-prevention devices as applied to water tank interiors appear to be a promising innovation, but general acceptance will probably be withheld until use has been more widespread and until there has been an accumulation of more evidence to support the claims made for the method. Certainly it should not be applied to structures already badly pitted, without making repairs, as the removal of rust tubercles from these tanks may tend to induce leaks at rivet heads and seams, and in such instances trouble would be promoted rather than reduced.

**Discussion by *T. H. Wiggin*.*** The writer has given considerable study to and, in fact, some ten years or so ago was connected with the installation of a considerable number of cathodic systems for the protection of boilers, feed-water heaters, and condensers. The type of equipment for that work is similar to that required for tanks, but much more care is required, particularly where the electric connections pass through the boiler, on account of the effect of the heat of steam and hot water.

* Consulting Engineer, New York City.

These installations were intended to prevent corrosion but principally to prevent formation of scale or other deposits which would prevent the transference of heat. As installed in these early stages of development, they frequently removed a great deal of scale but did not always prevent the formation of scale in all parts of the boiler. In condensers they kept the vacuum steady instead of allowing it to decrease by deposits on the condenser tubes and in this way were a help to steam economy. The writer has lost track of these installations and is not informed whether they have continued to give satisfactory service. They are only mentioned here to show the parallel development which considerably ante-dates the tank protection. This development itself is ante-dated by other types of cathodic protection for boilers on the same principle but somewhat different in detail.

On the exterior of pipes there is now a long history of cathodic protection extending back to the year 1905. The first patent for such work was a German patent granted in 1908. One of the early applications of the cathodic method was to a 60-inch steel gas main in New York City in 1915. A great many miles of gas and oil pipes and at least one water pipe, viz. the 72-inch steel main from the Mokelumne River which supplies the East Bay Municipal District, near San Francisco, have received cathodic protection during the past 10 years. The principles of cathodic protection employed for boilers, exteriors of pipe lines and water tanks are obviously similar in essential points. Even the use of carbon anodes so common in systems for protecting exteriors of pipe has its parallel in some of the tank installations.

The principle of cathodic protection has received theoretical endorsement from professors of electro-chemistry, and there are some industrial applications such as for the removal of scale from watch springs that have had scale formed on them in the tempering process.

The writer was told by an engineer engaged in the cathodic protection of tanks that their electro-chemical experts thought that the exterior of a tank would be aided as to corrosion and deterioration of paint by interior cathodic protection, but so far as the writer knows there have been no observations recorded regarding this point. Neither has the writer seen any description of observations made on the inside of pipes which have had exterior cathodic protection to see whether the exterior protection affords any interior protection. The expert with whom the writer worked on some of the early boiler

and condenser installations stated that it would be very simple to protect the interior of water pipes. Such an experiment was put on the program but was never reached because of the press of other matters. It would be interesting to know whether protection of the interior of a water pipe might at the same time accomplish the protection of the exterior and perhaps be cheaper in application.

### Use of Paint With Cathodic Protection

There is also the question whether any additional safe-guard is afforded by the application of paint in addition to cathodic protection. In the application of cathodic protection to the exterior of oil and gas pipe lines it is found that the presence of a good exterior coating greatly reduces the quantity and cost of the protective electric current. These costs are a considerable item in the protection of the exterior of pipe lines, but they appear to be of little moment in the protection of a tank. Yet it is reasonable to speculate that if the paint were protecting all but a certain number of pin holes or "holidays," then the cathodic process would have an easier time in taking care of those small points just as is found to be the case in the exterior protection of pipes. In the long run, however, the paint would be destroyed by natural causes and then the question whether to re-paint or to allow the cathodic process to pick up the whole load would arise.

There is also a question as to the advantage, if any, of sand blasting, shot blasting, or pickling the steel to remove the mill scale which tends to become dislodged and to carry away the paint with it. It would seem that if the interior of the tank were to be left bare and cathodic protection applied the process would remove the mill scale. But if the interior cathodic protection is helpful to the exterior paint then it might be advisable to take the mill scale off the exterior so that the paint would have a better chance for permanency.

These are all speculations which suggest themselves with a new process of this kind being exploited, and there is a wide field for investigations which remains to be explored.

There is one experience of which the writer has had rather close knowledge, i.e., the application of cathodic protection to a very old tank which was badly rusted. The application resulted in some leaks at rivets and seams caused by the sloughing off of rust following the application of the process. This would seem to indicate that care should be exercised in inspecting an old tank to see whether its

tightness is in part provided by the rust which has accumulated. It is to be hoped that not many tanks have been allowed to go so far on the road to destruction by corrosion; if so their owners might have to forego the benefits of the cathodic process.

It is obvious that more time will be needed before a true appraisal of the cathodic method as applied to tanks may be made, but the information so far received is nearly all favorable except as to the details of providing for the rise and fall of ice cakes on the surface of the water in the tank. Placing the anode beneath supposed low water in the tank appears to be a common method of providing for this difficulty, and spring supports have also been used. The writer has the impression, however, that the problem is not yet wholly solved for all cases.

It is also suggested that it may be desirable to install a signal light in the system with electrical equipment so that the light will show when the system is not working.

# Legal Decisions Relating to Distribution Of Public Water Supplies

*By Frank A. Marston*

IT IS a well-established principle of law that the operation of public works by a municipal corporation, as well as by a private corporation, is a proprietary function; and that the water authority is responsible for damages in the event that neglect is proven. In most of the states it must be established that the municipality or private company did something that it should not have done or neglected to do something that it should have done (1). The argument that the operation of water works is vital to maintaining sanitary and healthful conditions in a community, and is therefore a governmental function, has failed to relieve the water authority from responsibility. The argument that the operation of water works is in part for purposes of fire protection and is therefore a governmental function has also failed to shift the burden of responsibility, except where the damage claimed clearly resulted from the service of fire-protection service apart from that of water-supply service (2).

Damage in general may result from:

1. Leakage of water from the distribution system.
2. Water of quality injurious to health.
3. Water of quality injurious to industrial processes, goods, etc.
4. Structural defects in the system.
5. Lack of water pressure or lack of water.
6. Methods of construction contrary to generally accepted methods.
7. Careless work during construction.
8. Negligence in operating and maintaining water works.
9. Hazardous conditions on users' premises.

Negligence, if proven, on the part of an employee or agent makes the municipal corporation as well as the private corporation liable for damages.

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A paper presented on April 25, 1940, at the Kansas City Convention by Frank A. Marston, Partner, Metcalf & Eddy, Boston, Mass.

### Leakage From the Distribution System

The usual case involving damages due to leakage of water from the distribution system is that resulting from the break of a pipe. To prove negligence in connection with a pipe break, one or more of the following must be shown:

1. The installation of the pipe line was not legally authorized.
2. The design of the system, structure, pipe line or appliance was not in accordance with recognized good practice.
3. The materials used were not in accordance with recognized standard practice or good usage.
4. The method of construction was contrary to generally accepted methods of procedure.
5. The water authority failed to protect its pipe, knowing that work was being done by others that might endanger the pipe.
6. There were other breaks or leaks in the same locality and under similar conditions, which should have warned of probability of a defect. The defect should have been apparent or was not concealed.
7. Diligence was not shown in shutting off the flow of water or in repairing a leak.
8. An adequate number of shut-off valves was not provided.
9. Adequate provision was not made for maintenance or for handling emergencies.
10. Sufficient records were not kept as to the location of stop valves and other essential features of the distribution system.

While in most of the states it is necessary to establish negligence, the state of Minnesota seems to be an exception. In that state, the fact that water escaped from a pipe or reservoir seems to be the important fact and it is not necessary to prove negligence. The decision of the Supreme Court of Minnesota in *Bridgeman-Russell Co.* v. *City of Duluth* (3) discusses this rule in detail and gives a number of citations (4), including a reference to the English authority (5). In Massachusetts a municipality supplying water was held responsible for a leak in a standpipe which rendered it empty and deprived the service pipes of pressure, where due diligence in discovering the leak and starting the pumping engines was not used (6).

At Buffalo, N. Y., cellars were flooded by a broken main owned by the city (7). It was testified that a small truck, weighing about 3 tons, crashed through the center of the asphalt-paved street and

caused the break in the main, but the property owners contended that the city maintained the main in a dangerous and unsafe condition and did not take precautions to protect the property owners. The latter also contended that the city employees did not turn off the water promptly when notified of the break. It was further proved that, in the section broken, leakage from joints was washing away the pipe support, leaving the pipe susceptible to breakage from above. The final court found the city not liable but held that, if a city failed to prove its officers and employees used ordinary care, the property owners were entitled to recover damages.

According to a New York court decision, damages caused by a break in a water main cannot be charged to the city or water corporation, if the employees were not negligent in making the installation, if employees responded promptly when informed of the leaks, and if there were no other breaks in the same locality and under like conditions which should have indicated to the water-department employees that this particular main should have been inspected to determine the possibility or probability of a defect (8).

In Massachusetts, however, the city of Boston was not held liable for damages due to a bursting water main, even though it had previously repaired another break nearby, since the cause of the break in question was unknown (9). The court ruled that, when the city repaired the first break reported, it was not obligated to expose and examine all the pipes at the intersection where the break occurred.

In a western city, a contractor excavating in the street broke a water main, causing damage to a property owner who needed to obtain water but could not (10). Although the contractor had notified the city to make repairs, the court held him liable and the city not liable, because the contractor had interfered in the relationship between the municipality and the inhabitant.

In Richmond, Va., the city owned and installed the mains and accessories, including meters. A company leased a building, where water for a lavatory and washstand was supplied (11). The service pipe carried water from the main to a meter, located (about 18 in. below the ground) under the sidewalk and near the curb. After passing through the meter the water continued through the service pipe into the basement of the building, where pipe connections were made to the lavatory and washstand. One afternoon the manager discovered water running into the basement from numerous openings

in the front wall of the building, through which the service pipe entered. He notified the water department which immediately cut off the water at the meter, stopping the flow into the basement. The meter was removed and a new one installed. In the suit it was proved that two of the bolts and washers in the bottom of the meter had given way and allowed the water to escape. The city denied negligence, since the defect was latent and could not have been discovered by the exercise of ordinary care. The court held the city not liable because the defect was not susceptible to discovery.

A similar finding was made in a case involving the city of Grand Rapids, Mich., where a break occurred in an elbow of a lateral main, flooding a basement and causing serious damage to a stock of seeds (12). The owner of the seeds failed to prove that the defect could have been discovered and repaired by the city, and the higher court held the city was not negligent since the defect was concealed. The court ruled that actual notice of the defective condition of a water system, either by reason of knowledge of a break or an overflow at the point of damage, or by reason of a like occurrence, is prerequisite to a finding of negligence on the part of the owner in maintaining the system.

Other cases of leakage, in which diligence was not shown in shutting off the flow of water or in repairing the leak, are cited later in a discussion of cases involving negligence in operating and maintaining water works.

Cases involving water leakage usually relate to leaks in water pipes outside the customer's premises. The probable disposition of a case where the leak is in a service pipe on the customer's premises, but outside the building stop-cock, may be expected to follow the general rule that, if the water purveyor is to be held liable, there must be responsible control by the water authority and negligence must be proved.

### Water of Quality Injurious to Health

The courts have frequently held that water authorities are responsible for the quality of the water delivered to consumers (13, 14). Water may be contaminated either at the source of supply or during distribution, but this discussion relates only to cases of contamination of the water after it enters the distribution system.

Cross-connections in the distribution system between the pure public water supply and an impure private water supply may result

in pollution of the public supply (15). Polluted water from a sewer or cesspool may leak into a water conduit that is not under pressure. Failure to sterilize new water mains before placing them in use may result in contamination of the water passing through them. Leakage into underwater pipe lines when internal water pressure is removed may cause contamination of the water.

In the Pennsylvania Railroad case (16), involving a cross-connection, the court ruled that the city was bound to exercise reasonable care to see that no impure water entered its water main from a connecting railroad main. Since the water in the railroad main was taken from a typhoid-polluted river, both the railroad and city stood charged with notice of the character of the water. The court further held that the evidence sustained a finding that both railroad and city, in maintaining a check valve in the water main, were negligent and that such negligence was proximate, because of the intestate's death from drinking impure water.

In discussing a case in the State of Washington the court said (17): "It is sufficient to say that the evidence discloses that on April 11, 1923, a six-inch main was laid to connect two laterals, and that when the connection was so made it permitted free circulation of water to the city users in the district served, and also better service to the Eclipse Mill Company. At the time this connection was made, there was a by-pass which had existed for a great many years. With the making of the connection there was no longer any need for the by-pass. This by-pass had in it what is known as a gate valve A—a valve worked by hand, and which when closed, effectually prevented water from passing through the pipe. . . . There was evidence that the city never inspected the valve in the by-pass from the date of its installation. . . . The ease with which the valve could be sealed or by-pass removed and the imminent danger to be apprehended by failure so to do are strong factors in the question of the city's negligence." As a result of its finding the court awarded the plaintiff $60,000.

In a New Hampshire case, negligence was alleged in that the defendant municipal corporation failed to clean out its water pipes or to provide means of cleaning them out (18). Consequently, foreign and decayed matter became lodged in the city's pipes, entered the pipes leading to the plaintiff's dwelling and was there consumed by the plaintiff's intestate, causing him to sicken and die. The court held that the defendant was liable.

### Water of Quality Injurious in Industrial Processing

Operations of water works forces in flushing mains, testing the flow capacity of mains, and other work that may cause an unusual circulation of water in the system are likely to stir up sediment, with resulting possible damage to laundries and industrial processes and products. Breaks in main pipes may cause similar conditions. The water authority may be held liable for damage in such cases, but only if negligence can be proven. In the case of changes in quality of water due to fire flows, the water authority would probably not be liable.

### Structural Defects in the System

The water authority is responsible for damages resulting from defects in its structures. Cases in this classification commonly involve claims for injuries sustained in falling over projecting curb boxes or meter boxes installed outside the premises of the water taker, in the sidewalk or street. Other cases involve damages because of projecting gate boxes, manhole covers, etc. The following typical cases illustrate the attitude of the courts with respect to the responsibility of water authorities (19).

The Indianapolis Water Company was held liable by the higher court for damages sustained by a person who tripped over a projecting curb box and suffered severe injuries (20). The water company was deemed to have control over the service line and curb box, because it issued a permit to a plumber, who installed the service line for the property owner, and required the plumber to post a bond of $1,000 approved by the water company, and because the company retained the right to maintain or replace the service line between the main and the property line. The water company was held responsible to the traveling public, even though the company's rules provided that the water taker should maintain the service pipe and that the water company should not be liable for any damage caused by defects in any of the consumer's pipes or appliances.

A case in Texas also involved injury to a pedestrian from a defective curb box, which had been installed by a private party with the consent of the water consumer (21). In this case the water company exercised no control whatever over the installation of the private line or curb box, and the higher court held that, under the circumstances, the water company was not liable for injuries to the pedestrian.

A Missouri case is of interest, in that the highest court held that the customer may be required to install the service pipe and curb box and, when he has done so, they become appurtenances to his realty (22). The court further held that it was the duty of the customer to maintain and repair the service pipe and curb box, thus making the customer liable and not the company.

In Iowa a person sued for damages as a result of falling over a defective curb box (23). The higher court held that the curb box was maintained for the common use and convenience of the company and the property owner, and that it was clearly the duty of both to use reasonable care to see that the curb box was maintained in such a condition as not to be a source of danger to the traveling public. This case established that water company and consumer may be jointly liable and that damages may be collected equally from each.

It is possible, however, for a contract to be executed between the water authority and the property owner whereby the property owner can be made to assume full responsibility for damages caused by defective service pipe and appliances, even when the water authority and property owner may be held jointly liable in the first instance.

In Montana, a water company was held liable for the repair of a curb box projecting above the sidewalk, even though the cost of labor and materials used in construction of a connecting box was paid by the property owner (24).

### Lack of Water Pressure or Lack of Water

There have been cases involving alleged damage due to the failure of the water authority to furnish water under adequate pressure or due to furnishing water at a pressure far below the normal. The following typical cases indicate the decisions made by the courts relative to responsibility for such damage.

In a Connecticut case, the court ruled that a property owner had no claim against a water company for failure to conform to its contract with a municipality to supply fire hydrants with water (25). In Kentucky, on the other hand, a water company was held not to be relieved from liability for fire loss caused by frozen hydrants on the ground that freezing of hydrants was an act of God (26).

In Arizona, the court found a water company not liable because of failure to provide sufficient pressure in its mains (27). Similarly, the higher court held a water company not liable, for not supplying

sufficient water for fire protection, in compliance with the provisions of its franchise (28).

In 1908 a conflagration occurred in Tampa, Fla., which burned a large section of the city, and suits were filed against the Tampa Water Works Co. aggregating about $1,250,000. In one case the higher court ruled that plaintiff's property was not located where the fire started, that defendant was not responsible for starting the fire nor under duty to extinguish the fire, and that defendant did not fail to supply water as legally required (29).

The responsibility of a water company for fire protection was established in Kentucky by the Paducah case (30). Here the court held that the water company did not maintain its contractual obligations, because it did not furnish an adequate quantity of water for extinguishing the fire, and was therefore subject to damage for fire losses.

The North Carolina courts followed the Kentucky court in finding that a water company is liable to an owner of property destroyed by fire in case of failure to supply water and pressure at the time of the fire (31). In this case the plaintiff sued as a beneficiary of the contract between the city and the company.

In Tampa, Fla., fire caused by explosion of a gasoline lighting system destroyed one building and damaged goods in the next building. The owner of the building in which the fire started brought suit against the water company, on the ground that the company did not furnish sufficient water to put out the fire (32). The court held that the defendant assumed a "public duty of furnishing water for extinguishing fires according to the terms of its contract" and, for negligence in discharge of that duty, was liable in an action of tort.

Kentucky, North Carolina and Florida appear to be the only states which have held water companies liable to individuals and taxpayers for contracts made with the city for furnishing water for fire protection.

As typical of the many similar cases in which water companies have been held not liable, the Shreveport, La., case may be cited (33). Here the language of the court was as follows: "It goes without saying that no contractor would expose himself to a lawsuit in the wake of every fire, without exacting pay for so doing, and the pay would have to be very heavy, for . . . at any moment under such a liability, heavy damages might have to be paid, in fact a general conflagration . . . might utterly bankrupt the contractor. It is

entirely improbable that the city of Shreveport would have been willing to impose so heavy a burden upon her treasury."

### Construction Methods Contrary to Accepted Procedures

In case damage results from the use of construction methods other than those generally accepted, the water authority might be held liable, if the method used was enough different from the recognized methods to involve negligence, rather than a mere error in judgment.

Evidence of unstable soil, which should be expected to cause settlement and for which no provision was made, may be a basis for negligence, as in a Minnesota case (34).

Samuel J. Manning was asphyxiated on August 22, 1913, while asleep in his home in St. Paul, Minn. Immediate investigation by the gas company showed a large break in the service pipe at a joint or coupling in the ground, 5 ft. away from where it passed through the foundation of the building. The pipe which was 27 in. below the surface in peaty ground, had not been disturbed since Mr. Manning became owner of the house, about four years prior to his death. The complaint alleged negligence, in allowing the pipe to become damaged, defective and leaky. The higher court, finding against the defendant, spoke as follows:

"We think the evidence amply justifies the verdict. The character of the soil around Manning's home was such that it was liable to settle, yet the usual precaution to block the service pipe at the coupling or joint was not taken. That settling was considerable was shown by the fact that the sag of the pipe at the break was six inches. The soil was also of such character that the action of the frost was likely to heave or unsettle it to a great extent, and yet the pipe was placed at a depth of less than three feet. The evidence also tended to show no attempt in the original installation to plaster or make tight the foundation where the pipe passed through; thus a ready access to the basement was afforded the escaping gas."

Improper replacing of earth backfill in a street excavation was found to be a basis for negligence in a Pennsylvania case (35). Furthermore, the fact that a permit, granted to a water company to do work in a street, provided for a deposit by the company to be held for a certain time was found by the court not to warrant the inference that return of the deposit released the water company from liability for damages caused by the negligent replacement of dirt.

According to the decision in a New York case, in order to hold the water authority liable for damage due to improper laying of a pipe, negligence must be proven (36). In this case, an ice company brought suit against a water company, alleging an improperly laid water main, which finally broke, causing damage to the interior of the ice plant. The higher court held the water company not liable because the ice company failed to prove that the break occurred because of negligence.

### Carelessness During Construction

According to several court decisions, the water authority may be deemed negligent for careless work during the construction. A meter pit left uncovered by workmen may cause injuries for which the water authority is liable as in a New Jersey case (37). Injuries to workmen and to the public during the progress of construction work may involve the liability of the water authority, as in the case of other construction work.

In California, suit was brought against a contractor and a water district, which employed the contractor to construct a water tunnel, by a personal representative of one of the contractor's employees who was killed during the construction work (38). The court held that the water district was engaged in a proprietary and not a governmental function in constructing its water system and was accordingly liable in damages.

In another case, the same water district was held liable in damages for the loss of an eye of a passerby, when a piece of steel broke off a tool, which was being used by employees of the water district in connecting a water main in a city street, flew up and hit the passerby (39).

### Negligence in Operation and Maintenance

Many cases have been brought before the courts in which damages were claimed due to negligence in operating and maintaining water works. Some typical cases in this category are given below. Among them are a few involving damage due to breakage in pipes, where it was brought out that diligence was not shown in shutting off the flow of water or in repairing a leak.

In one case, in the southwestern part of the country, the higher court held that it must be proved whose duty it is to maintain a certain structure, the failure of which has caused damage, even though there may have been negligence (40). Specifically, the

court refused to hold a water company liable for destruction by fire, although negligence in keeping the fire plugs in proper condition was proved. There was no evidence as to whose duty it was to keep the plugs in condition.

In New Jersey, a water company was held not liable for the burglarizing of a vacant house from which it had removed a water meter, since it had subsequently closed the house as effectively as it had previously been closed (41). In Louisiana, a city supplying water was held not liable for a death by drowning in an excavation which had been made to repair a leak, since there was no reason to anticipate the death (42).

In the case of a Colorado public service company, which maintained a pipe line on a mountain side in a known slide area, the court held that greater care may be required in the maintenance of such a pipe than of a ditch in the plains (43). In Utah, moreover, a court held a city liable for damage to property which resulted from a landslide due to natural causes, on the ground that an improperly maintained pipe line contributed to the damage (44).

In a case where it was shown that a meter-box cover had been removed, causing a citizen to fall by stepping into the open hole, the city was held liable, because the citizen was not negligent and did not know of the specific defect which caused the fall. The court ruled that, where a sidewalk is defective and a pedestrian admits knowledge of its condition, recovery cannot be made, but that, where a pedestrian is unaware of the specific defect, he can recover (45).

In 1919, a damage suit in New York resulted from a break caused by the pressure of Catskill water upon an old main, which had been laid 47 years before (46). The original pressure was 25 lb. per sq.in. Where the pressure was increased by 10 lb. per sq.in., two breaks occurred in pipes in the neighborhood. Then, when the pressure was increased by an additional 10 lb. per sq.in., the break which brought about the litigation occurred. In the words of the court, "here no question of notice or knowledge is involved, it being apparent that all the facts were known to, and the situation perfectly realized by, the appropriate city authorities." The city was consequently held liable for damages.

In a suit brought by a Virginia city, the defendant, owner of a warehouse which was flooded, was found not guilty of contributory negligence, when city employees closed the wrong valve leading to a sprinkler system (47).

Courts have ruled in numerous cases that, upon being notified

of the existence of a leak or a break in a pipe, or the occurrence of a similar accident, the water authority is bound to use diligence in stopping the flow of water and in repairing the faulty pipe or appurtenance. Failure to do so may result in liability for damages resulting from the delay.

In a Massachusetts property owner's action for damages on account of a city's alleged negligent operation of water works, which caused flooding of a cellar, the evidence was held to sustain a finding that the city was negligent (48). The plaintiff owned a 42-family apartment building on Hanover Street in Boston. In 1932, five buildings in the rear of the building were torn down. While the last of these was being torn down, 1 ft. of water came into plaintiff's cellar, through the rear wall. Plaintiff brought the matter to the attention of the water department at once, but it was not until November, 1933, that the city repaired the broken water pipe.

In California, a water company was held liable for injuries due to a gas explosion which was caused by a street cave-in, resulting from a water pipe break (49). The jury found negligence in failing to repair the main or shut off the water promptly.

In a Kentucky case, the court ruled that a city supplying water is bound to use ordinary care to maintain its mains and pipes in proper condition and persons using water must use ordinary care to maintain in proper condition the pipes and fixtures upon their own property (50). Where a user's negligence concurs with that of the city in flooding his premises, he is not entitled to recover. On the other hand, where a municipality, after due notice that plaintiff's premises are being flooded by a leak from a pipe connecting with the city mains, fails to use ordinary care to turn off the water and avert the damage, plaintiff can recover under the doctrine of the "last clear chance," even though the leak was caused by his own negligence.

## Hazardous Conditions on Users' Premises

Water departments or companies are responsible for the quality of water received by their customers. That this responsibility may include the quality of water on the consumers' premises after passage through the service pipe is indicated in court decisions rendered during 1938 and 1939 (51, 52). Under some conditions the water authority may be responsible for damage caused by faulty service appliances.

There are several ways in which water may become contaminated after it leaves the street main and before it is drawn from a tap on

a customer's premises. Certain conditions may be dangerous to the public without affecting the city-wide quality of the water. Some of these hazardous conditions are as follows:

1. Character of material in service pipe may affect quality of water, causing water to become injurious to health.

2. Service pipe may be contaminated during laying, with the result that water passing through may contain harmful bacteria.

3. Poorly constructed water piping on the premises with resulting leaks, may provide opportunity for pollution to enter the water pipe from the outside, at times of negative pressure in the pipe.

4. Faulty flush-tank connections in hot and cold water systems may permit back-siphonage of contaminated water at times of negative pressure in the water pipe.

5. Improperly built water closets and supply faucets located below the maximum water level in bath tubs may be the source of pollution in the water pipe, due to back-siphonage.

6. Cross connections between the public water-supply system and piping containing an impure water may cause contamination of the public supply and injury or death to persons drinking the water.

7. Plumbing systems may be poorly constructed or soil pipes may be so located that in case of leakage open water tanks may receive pollution.

8. The reduction of pressure in a water main during a fire, when drafts are heavy, or at the time of a break in the main, may produce negative pressure in the water pipes with consequent collapse of hot-water boilers and withdrawal of water from heating boilers, later resulting in dangerous conditions and possible damage to life and property.

9. Improperly located service pipe, curb boxes, or other appliances may be a source of danger to the traveling public.

10. Leaks in service pipes may result either directly or indirectly in damage to persons or property.

In an English case, a man and his wife claimed damages for personal injuries due to lead poisoning contracted by drinking water supplied by the Irwell Valley Water Board (53). The water was not of dangerous quality in the main but was rendered so after passage through a lead service pipe. The higher court pointed out that the water board had been warned over and over again that water from a moorland source was likely to be dangerous if passed through lead pipes, and that the board had a duty to supply water of such a character

that it would be fit for domestic use. The court held that the water board might have corrected the solvent action of the water, or the water consumers might have been warned to put in a different kind of pipe or to draw off a sufficient quantity of water before using. In spite of complaints of illness due to lead poisoning, there was a long delay on the part of the water board, and this seems to have contributed to the negligence. Judgment was entered for the plaintiffs in the amount of £873 with costs.

In a recent Massachusetts case, the plaintiff, Horton, claimed damages for lead poisoning due to drinking water furnished by the town (54). Water supplying the plaintiff's house passed through 172 ft. of lead pipe between the water main and the meter. The water contained carbon dioxide to the extent of 30 p.p.m., and water standing over night in the service pipe showed more than 8 p.p.m. of lead. The state Supreme Court held that the town was liable on an implied warranty that the water was fit to be passed through the service pipe, approved by the town's agent, and then used in the house; and that the town was negligent in not taking reasonable steps, according to available knowledge, to correct the quality of the water.

In a case where it was shown that a Connecticut city failed to repair a broken service pipe, which flooded the cellar of a property owner, the higher court held the city liable, since, upon notification of an imperfection in the equipment affecting a property owner's premises, it was the city's duty to use ordinary and reasonable care to make the necessary corrections (55). In another case where a service connection was installed by a water company; some years afterward, when the pipe became rusty and caused damage, the company was held liable, in view of its contractual relations with the property owner, and in spite of the fact that the property owner had never paid his portion of the cost of the installation (56).

In Illinois, however, the court has held that a water company is not liable for maintenance of pipes and accessories belonging to the property owner (57). Similarly, in another case, where a property owner stumbled over a valve box on his own property, it was found he should be responsible for all repairs necessary from the main to the meter (58). Moreover, in a Montana suit concerning liability for injuries, due to failure to repair a pipe, it was decided that the property owner owns the water pipe and fixtures to the line between the lot and the street or alley, and the water company owns the pipe and fixtures beyond such line (59).

In Maine, a consumer's failure to have a check valve installed was held negligence preventing recovery, where a water tank collapsed when the water company shut off the water in the main (60). The water company's failure to inspect the consumer's appliance was not a waiver of the rule requiring the consumer to have a check valve between the water tank and the street main.

In New Hampshire, a water company, maintaining a hole in a cellar for a meter and using a cover constructed by someone else, was held responsible for discoverable structural defects therein (61). Knowledge, chargeable to meter readers, of a defective cover over the hole containing the meter was held to be knowledge of the water company.

Briefly summarized, water purveyors have generally been held liable for damages resulting from the construction or operation of water distribution systems only where negligence has been proven. Knowledge of leading court opinions in these cases will aid water works operators in conducting the business so as to prevent conditions that may cause damage, as well as to provide defense against unjust claims.

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# Modern Trends in Legal Liability

*By G. R. Redding*

THE author's first reaction to the subject of "Modern Trends in Legal Liability of Water Utilities" was that for years public suppliers of water have been subjected to such extensive and burdensome legal liabilities and obligations that there could not be much "trend." It will, of course, be understood that once a legal duty or obligation has been imposed upon an industry, and particularly one performing a public utility service, no "trend" relieving or removing that obligation is to be expected. A moment's reflection, however, brings to mind a few instances in which the legal hazards of public water suppliers have been extended and broadened, and study has disclosed others to the point that it may be said that there is a trend, in certain fields of liability at least, towards an increase and enlargement of the duties of a public water supplier both to its consumers and to the third party public.

In the major respects the municipally owned and operated plants stand on a like footing with privately owned and operated systems or plants in the field of liability, so the following remarks will have equal application to both. This is true because the general supplying of water to the public is not classified as a sovereign or governmental activity, so when a municipal corporation undertakes such service it is engaging in a proprietary (or private) function and loses its sovereign immunity from tort liability. Accordingly, as a matter of convenience, the term "company" shall be used in these remarks as identifying, and applying to, both municipal and private plants.

In many of the activities of water companies and of the employees engaged in carrying on their services, contacts with the public are exactly the same as would be the case in a strictly private business,

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such as manufacturing automobiles or selling or delivering general merchandise. A truck driver, for example, while operating a water company truck in the course of its business, causes an injury to a pedestrian. Liability in such case will be tested and determined by the rules which apply in such situations between private individuals or enterprises. The threatened tendency to impose upon an automobile operator the burden of an insurer against injuries to third party members of the public, which some experts in the field observe, will reach water companies, as well as other operators of motor vehicles, if it does come. The same observation may be made in respect to possible liability to one forcibly detained in the place of business, or one injured by falling into a dangerous pit or opening in the plant, or one who has suffered an assault or battery by one of the company's meter readers or other employees.

These comments, however, are not intended to cover the growing hazards imposed upon members of society generally by reason of the increasing complexity of our economic and social structures. The legal liabilities, to which attention is called, are those which arise out of a water utility's position as a regulated supplier of a necessary commodity under certain franchise rights and privileges sometimes inaccurately referred to as a governmental grant of monopoly. In this situation the utility generally is considered to be "holding out" that it will serve all who properly apply for its service. For its wrongful refusal to serve an applicant, the company may be answerable in damages to the party who has been denied service. Recent decisions in Alabama and Michigan indicate that the damages for which the company may be liable if a wrongful refusal to serve is established, may include any inconvenience and annoyance caused the applicant and any loss of rents, profits or use of his premises which may be attributed to such denial of service. This may be more far-reaching than the expense of obtaining a substituted service and it appears to be a departure from the rule requiring an injured person to take all reasonable steps to hold damages to a minimum.

Further, in connection with this subject of liability for failure to supply service to one properly applying, it may be ventured that there will be a gradual broadening of the territorial limits applied in determining who is a proper applicant. To date this term has been confined largely to owners or users of properties abutting the established mains, but concepts of public health and other theories of public welfare may cause commissions and courts gradually to adopt

the rule that water utilities are required to render service within the area of their franchise even though each extension of service required may not be economically sound. Such a rule has been applied respecting the contraction of unprofitable rail service.

On the subject of public health, of course, there is a duty to supply pure water, and in some instances the duty has been construed as requiring the supplying of potable water. Legal liability for failure in this respect has been firmly established by numerous decisions. The basis upon which these cases in the past have rested has largely been one of negligence on the part of the defendant company. That is that some negligence on the part of a company employee caused the presence of impurities in the water which resulted in damage to the consumer. Recently, in some decisions, a further and more extensive basis of liability has been suggested, and the rule has been advanced that the company warrants the purity of the water which it sells. If this rule is generally adopted, any one claiming to have been injured as a result of impurities in the water will only be required to prove the existence of such impurities and the resultant injury. No longer will it be necessary to prove that the impurities or foreign material gained access to the water as a result of negligence on the part of the company. In a recent case in Georgia this rule was carried to the point that a municipal water plant which supplied water to a company engaged in preparing and selling syrups designed for use in soft drinks was held liable on an implied warranty that the water was suitable for use in such syrups. The cause of complaint in that case was that the chloride of lime used in purifying the water caused the syrups to have an objectionable taste.

One field in which water utilities may be incurring new or additional liabilities is found in the growing installation of private fire protection systems. Generally companies have not been held responsible for fire loss resulting from a failure to maintain pressure in their mains sufficient to serve in fighting a fire. But the basis of this rule may not apply where the inadequate pressure causes a failure in a sprinkler system. Instances of this sort have not been observed but the application of rules established in cases of interruptions of service for other private uses warns that such liability may arise.

Finally, attention should be given to a trend which has recently become evident in Indiana. Probably most of the water systems in the state have been constructed on the plan of having the consumers provide and pay for the service pipes extending from the companies'

mains to the premises to be served. Under this factual situation, it long has been the practice to require the customers to maintain and repair their own service pipes and the companies have been responsible only for the condition of their own property—ending where the customers' responsibility begins. Recently, however, the Public Service Commission has seen fit to impose the burden of maintaining, repairing and replacing service pipes and appurtenances between the mains and the property line of the street upon the company. If this rule of the Commission is valid, any company against which it may be made will be legally obligated to bear an expense which heretofore rested upon the consumer.

Further, in a recent decision, the Appellate Court of Indiana held that the company may be answerable to a third party for injuries sustained from falling over a curb stop box which projected a few inches above the surface of the surrounding ground. This holding was made despite a record showing that the curb box had been installed by the customer and never had been used by the company because the lot in which it was placed to serve is unimproved. The theory underlying the Court's holding seems to be that the company's franchise right to use the streets for the placing and maintaining of its distribution system to which such service fixtures are attached by its permission and under its power of supervision, makes it responsible for any hazards directly or indirectly created to users of the public highway and resulting from the exercise of such franchise. This development appears significant.

# Annual Report of a Small Water Works

*By L. E. Jarvis*

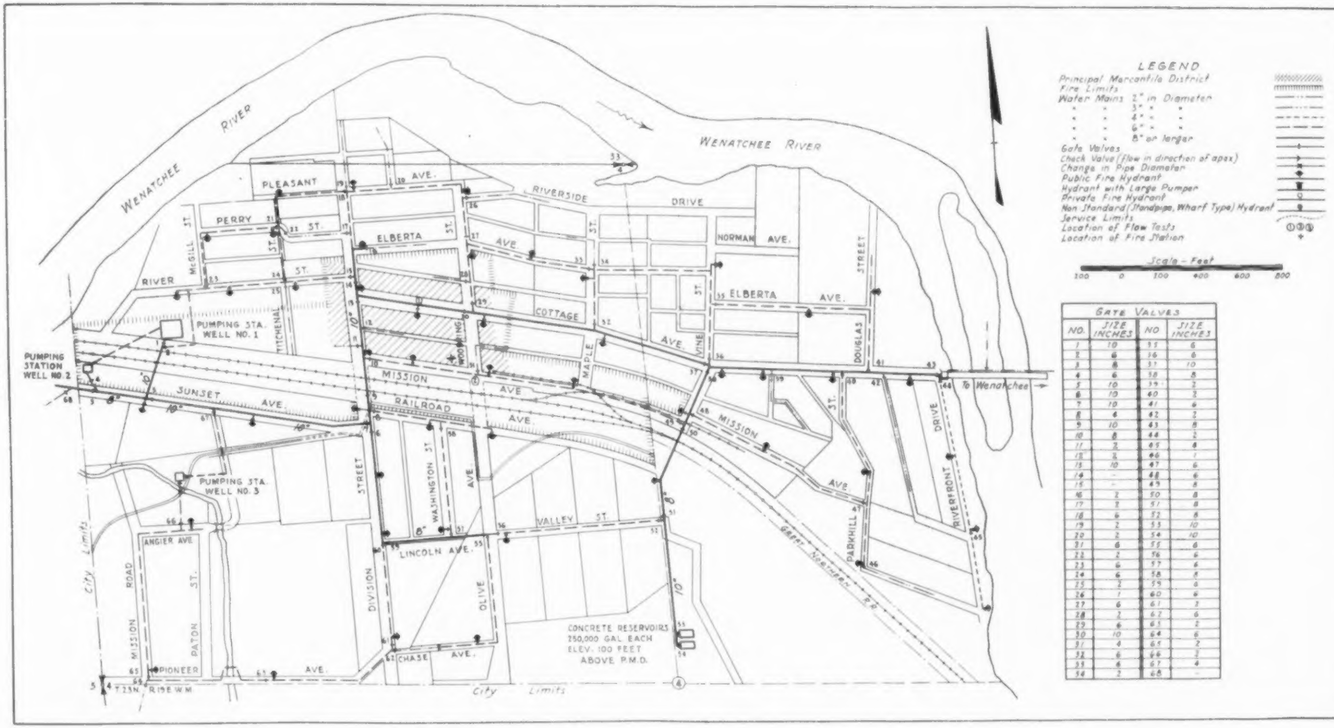
HEREWITH are presented selections from the annual report of a small water works. The author, as superintendent of the department (total personnel, 6) has, since his appointment, endeavored to establish complete records for all phases of the department's operation, as a basis for the institution of reasonable rates, efficient operation and a stable financial set-up. The annual report is an outgrowth of such a record, and serves not only to bring the information up to date, but to familiarize the customers with the data of operation, the savings effected, and the financial status.

The first attempt to initiate a complete record was the presentation of all information on equipment and fixtures in service in a map of the territory served (Fig. 1). This map is supplemented by separate books containing more detailed sketches of every street intersection and its physical arrangement.

Next item of the report presents the regular financial statements for the year (Exhibits A, B and C). Since these, however, give only summary information on actual operation, it was felt necessary to analyze them in further detail to show a more complete picture of all the various phases that entered into the operation of the system. Through the further breakdown of the items included, in the profit and loss statement especially, much valuable information has been found. A sample of the material will be indicative of its value:

The records indicated that during 1939, 164,280,000 gallons of water were pumped at a power cost of $1,160.14, or $.0083 per 1,000 gal. The average of all other costs per 1,000 gal. was $.0526, making total cost $.0609 per 1,000 gal. Income for the year was $11,125.16, or $.0680 per 1,000 gal.; making net profit per 1,000 gal.,

A paper presented on May 10, 1940, at the Pacific-Northwest Section Meeting in Portland, Oregon by L. E. Jarvis, Superintendent, Water & Light Department, Cashmere, Washington.




| GATE VALVES | | | |
|---|---|---|---|
| NO. | SIZE INCHES | NO | SIZE INCHES |
| 1 | 10 | 35 | 6 |
| 2 | 6 | 36 | 6 |
| 3 | 8 | 37 | 10 |
| 4 | 6 | 38 | 8 |
| 5 | 10 | 39 | 2 |
| 6 | 10 | 40 | 2 |
| 7 | 10 | 41 | 6 |
| 8 | 4 | 42 | 2 |
| 9 | 10 | 43 | 8 |
| 10 | 8 | 44 | 2 |
| 11 | 2 | 45 | 8 |
| 12 | 2 | 46 | 1 |
| 13 | 10 | 47 | 6 |
| 14 | – | 48 | 6 |
| 15 | – | 49 | 8 |
| 16 | 2 | 50 | 8 |
| 17 | 2 | 51 | 8 |
| 18 | 6 | 52 | 8 |
| 19 | 2 | 53 | 10 |
| 20 | 2 | 54 | 10 |
| 21 | 6 | 55 | 6 |
| 22 | 2 | 56 | 6 |
| 23 | 6 | 57 | 6 |
| 24 | 6 | 58 | 8 |
| 25 | 2 | 59 | 6 |
| 26 | 1 | 60 | 6 |
| 27 | 6 | 61 | 2 |
| 28 | 2 | 62 | 6 |
| 29 | 6 | 63 | 2 |
| 30 | 10 | 64 | 6 |
| 31 | 4 | 65 | 2 |
| 32 | 6 | 66 | 2 |
| 33 | 6 | 67 | 4 |
| 34 | 2 | 68 | – |

FIG. 1. Detailed Map of Water System

$.0071. Further, the report indicated that the daily average of water pumped was 450,081 gal., or 265 gal. per capita per day.

In respect to the additional pumping equipment installed, the report gave a separate schedule of comparative performance as described below. A direct saving to the light department is that effected by changing the pumping equipment to lower the kw.

EXHIBIT A—BALANCE SHEET, DECEMBER 31, 1939

*Assets*

| | | |
|---|---|---|
| *Current fund cash* | | $9,196.64 |
| *Consumers accounts receivable* | | 971.42 |
| *Inventory—Materials and Supplies* | | 2,277.31 |
| *Equipment, per Schedule 1:* | | |
| Pumping plant, building, fixtures and grounds | $3,500.00 | |
| Distribution reservoir and grounds | 8,114.87 | |
| Utility building and grounds | 305.26 | |
| Source of water supply (wells) | 6,764.03 | |
| Electric pumping plant equipment | 11,172.42 | |
| Distribution mains | 52,254.30 | |
| Hydrants | 3,000.38 | |
| Services | 14,012.82 | |
| Meters | 8,617.22 | |
| Utility equipment | 5.00 | |
| Miscellaneous equipment | 575.36 | |
| Office equipment | 557.37 | |
| *Total* | 108,879.03 | |
| *Less:* Reserve for depreciation | 30,873.52 | 78,005.51 |
| *Pumping Station land* | | 1,600.00 |
| *Total Assets* | | $92,050.88 |

*Liabilities and Surplus*

| | | |
|---|---|---|
| *Liabilities:* | | |
| Warrants outstanding | $4.50 | |
| Accounts payable (tax) | 51.45 | |
| Consumers meter deposits | 3,520.86 | 3,576.81 |
| *Surplus, per Exhibit C* | | 88,474.07 |
| *Total liabilities and surplus* | | $92,050.88 |

demand. Increase in the efficiency of the pumps results in a saving to the water department.

"Installation of a 400 g.p.m., 3-inch pump equipped with a 25 h.p. motor in the No. 2 Well, August, 1930, enabled reduction of peak load from 45 to 17.7 kw. for approximately 9 months per year, or a saving of 27.3 kw. × 114 months equalling $12,821.58. This

EXHIBIT A, SCHEDULE 1—EQUIPMENT INVENTORY, DECEMBER 31, 1939

*Pipe:*

| | | |
|---|---|---|
| Cast Iron—10″ | universal | 2,650′ |
| 10″ | bell and spigot | 500′ |
| 8″ | universal | 5,200′ |
| 8″ | pre-calked | 800′ |
| 6″ | pre-calked | 5,000′ |
| 6″ | universal | 11,200′ |
| 4″ | universal | 325′ |
| 4″ | steel standard | 200′ |
| Wood—6″ | laid in 1920 | 800′ |
| 6″ | laid in 1930 | 500′ |
| 4″ | laid in 1912 | 1,650′ |
| Wrought Iron—2″ | | 1,255′ |
| *Total* | | 30,080′ |

*Reservoirs*—2 concrete, capacity 500,000 gallons.

*Storage*—pump suction, including underground reservoir, capacity, 150,000 gallons.

*Pumping Equipment:*

#1 Well—1-turbine 6-stage pump, 25 h.p., capacity 520 to 650 g.p.m.
1-5″ pump, 100 h.p., capacity, 900 g.p.m.

#2 Well—1-4″ booster pump, $7\frac{1}{2}$ h.p., capacity, 400 g.p.m.
1-3″ pump, 25 h.p., 3600 r.p.m., capacity, 400 g.p.m.

#3 Well—Connected to main for emergency, water available, 400 g.p.m.

*Capacity and size of wells:*

#1—600 g.p.m., diameter, 16′ to 11′, depth, 43′
#2—300 g.p.m., diameter, 16′, depth, 32′
#3—400 g.p.m., diameter, 7′ x 7′, depth, 25′
Maximum capacity of wells for 3 hr. 1850 g.p.m.

*Fire Hydrants:*

| | |
|---|---|
| 4″ | 50 |
| 6″ pumper | 1 |
| 8″ master meter | 1 |
| 4″ master meter | 2 |

*Meters:*

| | |
|---|---|
| 4″ | 1 |
| 2″ | 10 |
| $1\frac{1}{2}$″ | 9 |
| $1\frac{1}{4}$″ | 4 |
| 1″ | 26 |
| $\frac{5}{8}$ x $\frac{3}{4}$″ | 468 |
| *Total* | 518 |

| | |
|---|---|
| *Services:* | |
| Metered | 528 |
| Unmetered | 2 |
| *Total* | 530 |

## EXHIBIT B

STATEMENT OF PROFIT AND LOSS FOR THE YEAR ENDED DECEMBER 31, 1939

| | | |
|---|---|---|
| *Revenues:* | | |
| Commercial water metered | $10,437.13 | |
| Municipal water for fire | 120.00 | |
| Municipal water for parks | 360.00 | |
| Miscellaneous operating revenues—Penalties | 114.00 | |
| Other miscellaneous revenues | 94.03 | $11,125.16 |
| *Less—Expenses:* | | |
| Discounts and Adjustments | 77.95 | |
| Operation of pumping plant | 2,335.51 | |
| Operation of distribution system | 752.52 | |
| Maintenance of electric power pumping plant | 130.06 | |
| Maintenance of distribution system | 551.60 | |
| Commercial office salaries and expenses | 1,600.32 | |
| General office salaries and expenses | 746.10 | |
| Miscellaneous general expense | 502.29 | |
| Depreciation and amortization | 2,921.52 | |
| Utility equipment expense | 178.20 | |
| Losses accrued C.A.P. | 2.00 | 9,798.07 |
| *Net Profit* | | $1,327.09 |

## EXHIBIT C

STATEMENT OF SURPLUS FOR THE YEAR ENDED DECEMBER 31, 1939

| | |
|---|---|
| *Balance, January 1, 1939* | $87,530.49 |
| *Less*—Delayed losses accrued in prior periods | 383.51 |
| *Adjusted Balance* | 87,146.98 |
| *Add*—Net profit for the period, per Exhibit B | 1,327.09 |
| *Balance, December 31, 1939* | $88,474.07 |

amount less the cost of the pump and equipment, $1,302.12, shows a net saving of $11,529.46 since the pump was installed.

"A saving was also shown in the cost of current on the operation of the new turbine pump over the cost of the previously used 5-inch centrifugal pump powered with a 100 h.p. motor with a demand of 45 kw. or 59.30 h.p. The turbine pump, powered with a 25 h.p. motor, actually pumps as much water as was pumped with 100 h.p., thereby lowering cost per 1,000 gal. from $.0096 to $.0057, a saving of $.0039 per 1,000 gal.

"The turbine pump will now be operated automatically, controlled with a time clock set to operate the pump only when peak demand is down enough to take care of pump demand, or when the reservoir is low enough to allow the pump to operate on 17.5 kw., which again will save approximately 17.5 kw. × $4.12 per kw. × 9 months, the part of a year we could stay off the peak, a saving per year of $648.90."

The final document attached to the report is a printed form of the rules and regulations of the department. This form, distributed to every consumer, sets forth the rates and practices of the department. Its opening statement indicates its purpose:

"These rules are a part of the contract entered into by every consumer of water and electric light and power. . . .

"Every rule is based upon the desire of the Water and Light Department to furnish water and electric light and power at the lowest possible rates.

"Failure to know the rules will not excuse you from penalty for their infringement."

*Editor's Note:* This material is brought to the attention of JOURNAL readers because it represents the ideal type of information which every water department superintendent should have at his command and which he should endeavor to bring to the attention of his customers. The managers of many water plants over the country will do well to observe that this report relates to the work of a department which has only 530 services. This record should challenge many men to improve their own records and methods of bringing their work to the customers' attention.

# Is It Profitable and Practical to Have Accurate Meters, Sensitive to Low Flows?

*By LaVerne Trentlage*

BECAUSE on certain data obtained in the past twenty months and because of more recent low-flow and test accuracy developments, the author is now thoroughly convinced that it is profitable and practical to maintain high accuracies on flows as low as one fourth of a gallon per minute on small meters.

It is safe to say that 95 per cent of all water works men have a good deal to learn about the various sizes of flows that pass through their small meters. This is said in all sincerity and fairness to that group of gentlemen. Those who have made studies of the subject have found that, of the water used in the average home, about 11 per cent is used at a rate of 10 to 12 g.p.m.; 47 per cent at 4 to 6 g.p.m.; 22 per cent at 2 g.p.m.; 10 per cent at 1 g.p.m.; and 5 per cent each at $\frac{1}{2}$ and $\frac{1}{4}$ g.p.m. On the basis of this information it will be well to analyze the flows to see what points of special interest or practical value may be gained.

First, it will be noted that in the bracket from 6 g.p.m. down through $\frac{1}{4}$ g.p.m., 89 per cent of the money is "made or lost." Then, too, it is interesting to find that the bracket from 1 g.p.m. down through $\frac{1}{4}$ g.p.m. includes 20 per cent of all the water used in the average home. In this connection it should also be realized that the $\frac{1}{4}$ g.p.m. flow is much different from that through a $\frac{1}{4}$-inch orifice; flow depending upon the pressure, this size orifice will deliver from 1 to 2 g.p.m., or even more. When individuals state that their meters test such and such an accuracy on the "$\frac{1}{4}$," it should be determined whether reference is made to g.p.m. or orifice size so that true value may be indicated.

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A paper presented on May 24, 1940, at the Illinois Section Meeting at Chicago by LaVerne Trentlage, Foreman, Meter Division, Water Dept., Elgin, Ill.

In discussing the significance of these various figures and their peculiar relation to the problems faced in the Elgin water department the author intends to develop the subject by means of the "question-and-answer" method, with the idea that the greatest clarity of expression can be achieved through this technique.

*How representative are the figures given in the above analysis?*

The figures are based on the analysis of the Elgin consumers. I feel, however, that the figure of 20 per cent given for the lowest bracket is a conservative one. This belief is founded on the knowledge that 87 per cent of the Elgin consumers own their own homes; by virtue of that fact they are thrifty and the large majority keep their toilets and faucets under strict repair, showing, too, that they are water conscious. In another city, however, where a large number of consumers rent their homes and do not pay the water bill, gross neglect of plumbing repair has raised the total in the group to as high as 35 per cent according to reports. (Our own findings showed 29 per cent.)

*How many consumers do you have in this bracket, and do you know how accurate your meters are on the various sizes of flows as outlined?*

In Elgin, we have completed our research work in testing large groups of various makes of meters merely to find out how *we* stand along this line. Now let me show you how a water department can suffer humiliation as a result of "cock-eyed accuracies."

In the first of three groups we tested 181 $\frac{5}{8}$-inch meters having open type gear trains. These meters had never been out of service since original installation, 26 years before, and had a total average registration of 175,000 cu.ft. per meter.

To make certain that the various sizes of flows were correct in gallons per minute we employed brass orifices drilled for our pressure, and for further exactness on the flows from 1 g.p.m. down through $\frac{1}{4}$ g.p.m. we used calibrated glass funnels. I suggest that you hold up a $\frac{1}{4}$ g.p.m. funnel under the flow you've been thinking is $\frac{1}{4}$ g.p.m.; then try the $\frac{1}{2}$ and 1 g.p.m. funnels in the same way. You may be surprised. We were! The results of the tests are shown in Table 1.

Upon repairing this group we converted all the meters over to oil-enclosed gear trains, installed new measuring chambers, disc-pistons, etc., at an average cost of \$4.45 per meter. This cost was for parts only; labor amounted to \$1.10 per meter.

As the total-parts cost was \$805 and the pro-rated loss in revenue

for the previous year was nearly $600 (because of declining accuracies), we figured that in 18 months the meters would pay for their repairs. From there on it is our "gravy," and not the consumers as it was in the past. Incidentally, this group, on the ¼ g.p.m. flow, tested 96.75 per cent, while on the high spot it did not exceed 101 per cent. Quite a difference in accuracies compared to those before repairs were made!

TABLE 1

*Results of Tests on 181 ⅝-inch Meters*

| METER SIZE | OVER-ALL ACCURACY ON FIRST TEST | PERCENTAGE OF "DEAD" METERS FOUND BY FURTHER ANALYSIS |
|---|---|---|
| *g.p.m.* | % | % |
| 12 | 91.71 | 8 |
| 4 | 88.80 | 9 |
| 2 | 82.74 | 13 |
| 1 | 66.38 | 26 |
| ½ | 38.98 | 51 |
| ¼ | 11.86 | 78 |

But the most interesting part is this. You know how a swell dessert tops off a big dinner? Well, after this repaired group had been back in service and had had one full quarter to work, our service department investigated more high-bill complaints than at any other time in its history.

By the way, the minimum registration per meter in this group of 181 meters was 100,000 cu.ft., the maximum was 300,000. Our break-down chart clearly shows that the higher the total registration per meter the more and faster the accuracies dropped, the more revenue the city lost, and the higher the cost of repairs. An illustration will demonstrate this last:

| | 100,000 CU.FT. | 300,000 CU.FT. |
|---|---|---|
| Average accuracy over-all flows | 88.27% | 61.40% |
| Average cost of repairs | $3.01 | $5.56 |
| Average loss in revenue per consumer per year | $1.40 | $10.61 |

*What was your immediate reaction to this particular group of meters?*

Well, after observing these figures and comparisons I automatically said: "Wow! How many more meters have we in service in the same

condition?" Because the Meter Department in Elgin is annually appropriated a limited amount of money, we could not possibly repair all of the remaining meters at once, but we did repair nearly 1,000, beginning with those meters having the highest registrations. In other words, the meters that were losing the most money were repaired first. Also, annually, meters not worth repairing, and losing the most money, we junk first.

By the end of 1940 the highest registrations remaining in service will include those of 80,000 cu.ft. Yes, we are rejoicing because "blue sky" is beginning to appear.

In the tests on the other two groups of meters there is little more to say than that they tested from 104 to 110 per cent fast over-all-flows, and that we buried them with no further ceremony. They were cheap meters both in price and performance, something on the order of the modern P.W.A. meter. I mention that because when any community is exploited to the place where they must accept a meter, the cost of which is under $8.00, you can write it down in your family album that that poor water department is "stuck" in more ways than one. Such low-priced meters can give only cheap performance, and so-called cheap meters are actually most expensive. Your cost of maintenance, should you keep them, will be unjust; the over-all accuracies, "cock-eyed," while you and many of the consumers will be "plenty disgruntled." Time alone will prove my prophecy one way or another; it just isn't "in the cards" for these meters to give a high grade performance.

After compiling the above data on the behavior of meters I could not help but wonder how a group of meters, having the *oil-enclosed* gear trains in them at the time of *original* installation, would test. Being in service practically as long as the meters of the 181 group and having the same amounts of total registration, they were really comparable. The results of the comparison are shown in Table 2.

The answer to the amazing differences is the oil-enclosed gear train. By the way, those few who condemn it stand alone in their belief.

*Thus far the flows that are actually used in the home have been discussed but what about those flows in the homes where the water is misused or wasted?*

In August, 1939, our service man made the following remark to me: "Boy, we certainly are having a lot of high bills to investigate lately, and the chief cause to date is leaking toilets, water running into the

over-flow pipe inside the box." He hadn't left my office more than three minutes when it dawned on me to have a check-up made, taking from our office files data about all high bills caused by a leak only from January 1 to November 1, 1939.

It was found that, during that period, 271 high bills were due to leaks (in the toilet, pipes, etc.) that passed through the meter. The purpose of our program was to investigate the 271 accounts where abnormally high bills were caused by a leak. We learned that $1,229.84, or $4.54 per quarter, was wasted by leaks of all types. The toilet was the biggest offender as $1,084.23 of the total amount; $4.30 per account per quarter was attributable to toilet leaks. More than 99 per cent of the consumers had the leaks repaired immediately after being informed; and it was noted that bills dropped to normal the following quarter.

TABLE 2

*Comparative Tests on Open-Train and Oil-Enclosed-Train Meters*

| TYPE | REGISTRATION, 100,000 CU.FT. | | | REGISTRATION, 300,000 CU.FT. | | |
|---|---|---|---|---|---|---|
| | Accuracy | | Ave. Cost of Repairs | Accuracy | | Ave. Cost of Repairs |
| | 12 g.p.m. | $\frac{1}{4}$ g.p.m. | | 12 g.p.m. | $\frac{1}{4}$ g.p.m. | |
| Open train | 101% | 37% | $3.01 | 94% | 0%* | $5.56 |
| Oil-Enclosed trains | 103% | 100% | $1.10 | 101% | 89% | $1.72 |

* All dead.

This information was very gratifying to all concerned and also surprising. It was particularly astounding to learn that the average toilet leak would amount to $4.30 per quarter, over and above the normal water bill.

With this information, I presented the report to the City Council. If it were not for the fact that 99 per cent of all bills dropped back to normal upon repairing the leaks, two members would still doubt that amount of $4.30 for a leak that is practically hidden from the eye. Most of the leaks were small and silent. Some consumers admitted observing the water easing into the over-flow pipe but certainly had no idea that it meant more than $4.00 a quarter. As a matter of fact nearly all the consumers would not believe the leak was the cause until after repairs were made and the next bill had dropped back to normal.

There are two main features about a leak passing through the meter: (1) It is constant and usually silent—day and night; whether we are eating, sleeping, working, or away on vacation, the leak continues. (2) If your meters are sensitive and accurate enough to register this flow, the results are that each passing minute this flow is earning additional money for the department, over and above the normal water consumption.

In this connection, it is interesting to note that in 11 months enough income resulted from leaks alone to pay for more than 100 new $\frac{5}{8}$-inch meters.

One of the most outstanding phases lacking in the above report is the fact that we did not know what the average leak amounted to in g.p.m. It was suggested that we pro-rate the leak against the $4.30 per quarter, but to do that would be entirely theoretical. Beginning January 1, 1940, every water bill at $1.00 higher than normal was investigated by our service man in the usual way. If any leak or water-cooled refrigerator was found, a recording register was used. To date we have gathered 31 charts, and from an analytical standpoint the results show: $403.32, or $13.01 per account per quarter, as the amount wasted by leaks of all types; and $224.56, or $9.76 per account per quarter, as the amount wasted by leaks in toilet only.

A further break-down of the toilet leaks shows that 29 per cent were in the bracket between 2 g.p.m. and $\frac{1}{3}$ g.p.m.; that another 29 per cent were in the bracket between $\frac{1}{4}$ g.p.m. and $\frac{1}{6}$ g.p.m.; and that 42 per cent were leaking at rates of flow from $\frac{1}{8}$ g.p.m. down through $\frac{1}{25}$ g.p.m. The average toilet leak was at the rate of approximately $\frac{1}{3}$ g.p.m.

From the above analysis it can be seen that the average toilet leak amounted to approximately $\frac{1}{3}$ g.p.m., or 43,200 additional gallons per quarter, over and above normal bill. Being tremendously interested in more revenue, we also observed from the report that a leak, as small as $\frac{1}{10}$ g.p.m., running for one full quarter will raise the normal bill 13,400 gallons or 1,780 cu.ft., for instance with a normal bill for 1,300 cu.ft. at $2.78, a leak of $\frac{1}{10}$ g.p.m. or 1,700 cu.ft. would make the bill for 3,000 cu.ft., or $5.50.

Here are a few statements that should be considered: 70 per cent of the toilets are leaking—if not today they will be shortly; 75 per cent of all toilets leak at some time during the year; 50 per cent of the cheap "competitive" flush boxes leak all the time.

The Water Department is always the winner, financially, in this leak business, provided that the meters are accurate in catching these small flows. If the consumer does not repair the leak they pay for the wasted water anyway. On the other hand when they do repair their leaks, pumping costs are automatically reduced.

For the average home, let us take one more panoramic view of the various size flows:

| | *gal. per min.* | | *gal. per min.* |
|---|---|---|---|
| (1) Actually Used: | 10–13 | (2) Wasted: | 2 or 129,600 gal. per quarter |
| | 4–6 | | $\frac{3}{4}$ |
| | 2 | | $\frac{1}{2}$ |
| | 1 | | $\frac{1}{3}$ or 43,200 gal. per quarter |
| | $\frac{1}{2}$ | | $\frac{1}{4}$ |
| | $\frac{1}{4}$ | | $\frac{1}{5}$ |
| | | | $\frac{1}{6}$ or 21,600 gal. per quarter |
| | | | $\frac{1}{8}$ |
| | | | $\frac{1}{10}$ or 13,450 gal. per quarter |
| | | | $\frac{1}{20}$ |
| | | | $\frac{1}{25}$ or 5,184 gal. per quarter |

*All* of these flows actually exist within our water systems, both in the form of used or wasted demands, from the 13 down through the $\frac{1}{25}$ g.p.m. flows. Our aim is to gain and maintain all the residential meters at such sensitivity and accuracy that whenever they are called upon to record the flows, as shown, they will be ready and able.

Thus far I have shown (1) the various sizes of flows and the percentage actually used in the average home; (2) the way our meters behaved on test on the various flows as outlined, and especially how the accuracies declined or rose in relation to the increasing amounts of registration; and (3) the amazing differences in costs and accuracies between the groups having open and those having oil-enclosed gear trains.

As a result of the above facts we saw that it would be both profitable and practical to maintain our house meters at high accuracies for over-all flows.

*What do you call high accuracies, and are they practical?*

In any water department money is made in two ways: (1) directly, through meters, that is the revenue from sale of water; and (2) indirectly, through the repair department, the absolute hub of the department.

Beginning in the middle of 1938, the following accuracy specifications for house meters were set up:

1. New $\frac{5}{8}$-, $\frac{3}{4}$- and 1-inch meters must test 98 per cent or better on the $\frac{1}{4}$ g.p.m. flow . . . oil enclosed gear trains.
2. Repaired $\frac{5}{8}$-, $\frac{3}{4}$- and 1-inch meters must test 95 per cent or better on the $\frac{1}{4}$ g.p.m. flow. (Having new measuring chamber and disc-piston.)
3. Repaired $\frac{5}{8}$- and $\frac{3}{4}$-inch meters must test 92 per cent or better on the $\frac{1}{4}$ g.p.m. flow. (Using original measuring chamber.)
4. Repaired 1-inch meters must test 90 per cent or better on the $\frac{1}{4}$ g.p.m. flow. (Using original measuring chamber.)

*When you install a new meter, how many years do you leave it in service before you remove it for testing, adjusting, etc., in other words, what is the life of a water meter?*

The life of any meter, regardless of its size, should depend upon certain low-flow accuracies below which you do not want the meter to fall. It is the accuracy that wears out; not the casing, bottom, bolts, etc. In Elgin, when the $\frac{1}{4}$ g.p.m. accuracy has dropped from the initial accuracy of 98 per cent to 90 per cent, we remove the $\frac{5}{8}$- and $\frac{3}{4}$-inch meters for testing and repairing if necessary. On the 1-inch meter, it is when the accuracy has dropped to 90 per cent on the $\frac{1}{2}$ g.p.m. flow.

*How many years will these accuracies hold before they reach the 90 per cent level?*

Your water will be largely responsible, but to be more exact I feel safe in saying that in water of 15 gr. $\pm$ hardness the 90 per cent accuracy on the $\frac{1}{4}$ g.p.m. flow should not be reached before 8 to 10 years time limit or by total amount of registration, between 100,000 and 125,000 cu.ft. For the 1-inch meter the 90 per cent accuracy on the $\frac{1}{2}$ g.p.m. flow should not be reached before 900,000 to 1,000,000 cu.ft. reading. In much softer water (5 to 7 gr. hardness) both time limit and total registration can be stepped up appreciably provided that the water is kept at near stability. In much harder water all time and total registration limits will have to be worked out locally.

*What is it going to cost? Is it going to be both practical and profitable?*

Absolutely yes! And I can only say from experience that the actual cost of either the $\frac{5}{8}$-, $\frac{3}{4}$- or 1-inch meter will not exceed the

price of one disc-piston and one bottom gasket for the first 2 cycles of testing and repairing, i.e. 16 years. While the $\frac{1}{4}$ g.p.m. accuracies should easily rise to 96 per cent or higher for all three sizes of meter!

A few examples of 1-inch meters repaired in 1940 and the parts required are:

| *Parts Used* | *$\frac{1}{4}$ g.p.m. Accuracy in per cent* |
|---|---|
| 1. Measuring chamber and disc piston, cleaning only; one bottom gasket | 98 |
| 2. One disc plate; one #24 ball-set only; one bottom gasket | 98 |
| 3. Chamber and disc piston cleaned; one bottom gasket | 95 |
| 4. One #25 ball-set; one bottom gasket | 94 |
| 5. One #24 ball-set; one bottom gasket | 97 |

When the above 1-inch meters were brought in for routine testing, regardless of how many years in service or the total amount of registration, no meter fell below 88 per cent accurate on the $\frac{1}{2}$ g.p.m. flow.

Just a word concerning the "repair department."

First, a pre-requisite is to have men who know their "stuff" and are beyond the shadow of a doubt 100 per cent honest and interested in progress. You may have repair men in your employment for from 10 to 30 years. "Experience" alone will never in a hundred years make them as efficient as they should rightfully be until they have had the benefits of research made available to them to show the how's, why's, and wherefor's of meters and to teach them certain principles involved—then, with their experience, they will be really qualified. As a matter of fact, their low maintenance costs plus the improved test accuracies on the $\frac{1}{4}$ g.p.m. flow will "prove" their ability.

Next, bring your testing equipment up to the minute—it will pay for itself in no time.

For verification of this, I suggest that you read my article entitled "What Does It Cost to Repair Meters?"* Let your meter men read it, too.

At the conclusion of 1938, after we learned that we had metered 74.2 per cent of all water pumped, we decided, in 1939, to try to account for every gallon of water that it was physically possible to

* *Water Works Engineering*, Jan. 3, 1940.

check. After this decision we accounted for 82.7 per cent of all water pumped, in the following manner:

| | |
|---|---|
| Water metered | 652,795,709 gal. or 79.5 per cent |
| Flat rates for construction | 574,649 gal. |
| Filter surface wash | 731,500 gal. |
| Estimated use on free services, metered for short period only | 721,122 gal. |
| Flushing mains and washing streets | 5,000,000 gal. |
| Leaks in distribution system | 19,576,700 gal. |
| Fires | ? |
| Sewer flush (not metered; very little done to date) | ? |
| | 26,603,971 gal. or 3.2 per cent |

In the above record you can see that we metered 79.5 per cent, an increase of 5.3 per cent over 1938. But we are now ready for the big moment of adding up the miscellaneous water used or wasted that did not pass through the meter system. The mere thought of having repaired scores of leaks in the distribution system alone, to the extent of nearly 20,000,000 gallons, while accounting for 5,000,000 more gallons by way of hydrant and street flushings, plus several other minor methods of accounting, gave us visions of raising the percentage still further to 85 or 86 per cent. To our utter disappointment, however, the final figure was 82.7 per cent or a further increase of only 3.2 per cent over what we actually accounted for through metering.

One fact in particular, that we all agreed upon, was that it was going to be a long difficult job getting to the place where we were really accounting for as much as 85 or 90 per cent, which is our ultimate objective.

*Where do you think the trouble lies?*

If we accepted the 60 year old belief that 15 per cent of all water is lost through pipe deterioration, we would then have an answer of 97.7 per cent. That figure we would like to accept, but recent research figures show only 2 per cent, not 15 per cent, lost through pipe deterioration, so we had to find another clue. The only remaining, fact possible was the gross inaccuracy of the meters. Immediately after analyzing the condition of our meters, as already mentioned,

we could not help but think we were on the right track; then, too, by repairing over 1,000 meters in 1938, we earned dividends, for in 1939 the percentage of water accounted for gained more than 5 per cent.

We know and admit that there are meters in Elgin that should be junked, while many, many, more are badly in need of repair. Through the faithful and systematic functioning of the meter department together with a fairly tight distribution system, however, it should be possible to reach our goal in a few years.

I, personally, know of other cities where the meters are really in bad condition from an accuracy standpoint, yet they claim they are accounting for more than 85 per cent. Again I repeat: "It just isn't in the cards!" Unhesitatingly we admit an abiding faith in accurate meters, sensitive to low flows. Our increase in revenue in 1939 over 1938 was $7,760, all due to the increased accuracy of the meters. Our pumping costs have been appreciably reduced owing to the scores of repaired leaks both within the metered and unmetered distribution systems.

Now, I should like to ask you the question: "What else can we believe but that it is both profitable and practical to have accurate meters sensitive to low flows?"

# Active Problems in Water Purification

*By Paul Hansen*

AS IN other fields of endeavor, progress in water purification is marked by intensification from time to time on certain phases of the practice; such intensification being stimulated by necessities, failures, new discoveries, public reaction, or the outstanding initiative of individual workers. Older water works men recall active, not to say heated, discussions on slow sand filters versus rapid sand filters, the effectiveness of filtration in reducing typhoid fever, the validity of the Mills-Reincke theory, the dollar cost in human life and sickness resulting from impure water supplies, lime and iron versus alum as a coagulant, and on chlorination as a factor of safety or as an aid to filtration. Some of these old problems are revived from time to time in the light of new experiences.

A review of the literature of water purification practice during the past few years and contact with many men active in the field indicates active interest in a wide range of subjects, but the dominant note that runs through most of the discussion is the serious realization that tightening of control is necessary to insure a safe and satisfactory water supply at all times and at all places on the distribution system. A series of events has been instrumental in bringing about this attitude.

First was the gastro-enteric outbreak in Charleston, West Virginia, in 1930, attributed to the public water supply, even though analysis indicated the water to be safe. This raised a question as to the existence of decomposition products or other disease producing substances that cannot be removed from heavily polluted waters by available methods of purification and which are not detectable by any known method of water analysis.

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A paper presented on April 25, 1940, at the Kansas City Convention by Paul Hansen, Greeley & Hansen, Hydraulic and Sanitary Engineers, Chicago.

Second was a paper, in 1931, by Gorman and Wolman (1) on the significance of water-borne typhoid fever outbreaks from 1920 to 1930, which study called sharp attention to imperfections in water supply systems and lapses in operation that permitted water supplies with modern purification equipment to become vehicles of disease.

Third was the violent epidemic of amoebic dysentery in Chicago, attributable to defective hotel plumbing. This gave great emphasis to defective plumbing as a danger to the quality of a piped water supply and brought into prominence a disease not previously regarded as water-borne.

Fourth was a typhoid epidemic in Minneapolis in 1935, attributed to a public water supply having up-to-date purification works. While the mode of transmission of the disease in this epidemic is still obscure, it raised the question as to the reliability of modern filtration works in preventing the passage of typhoid organisms. In addition, it raised a question as to adequacy of well established analytical procedures in detecting the presence of dangerous pollution.

Fifth was the epidemic of gastro-enteritis in Milwaukee in 1938, resulting from insufficiently chlorinated water. The epidemic occurred during a period when an old intake, known to be subject to relatively heavy pollution under certain conditions of wind and river flow, was in temporary use pending the completion of a filter plant. Though the authorities were on the alert, the results of analyses of water from the distribution system failed to yield results that were regarded as significant as measured by U. S. Treasury analytical standards. This occurrence focused attention on the fact that analytical standards alone cannot be relied upon without also evaluating the hazard of clumping of bacteria in a resistant mass where water is subjected to chlorination only.

Sixth was the timely preparation by Gorman and Wolman (2) of a second report on the significance of water-borne outbreaks, including other diseases as well as typhoid, in the United States and Canada from 1920 to 1936.

Seventh was the typhoid epidemic in 1939, at the Manteno State Hospital in Illinois, a catastrophe resulting from failure to heed the warning of a number of unfavorable analyses.

Tightening of control now appears to have taken possession of the minds of water works men as urgent in all matters relating to the quality of water served to the public and this attitude may be noted in the discussions of water purification practice that follow.

## Better Raw Water From New Sources

Within the past decade a number of cities have sought new sources of water supply, not because the old supplies were inadequate, but to obtain a better raw water that could be purified more reliably and economically.

Toledo, Ohio has under construction a project costing nearly $10,000,000 for obtaining a new water supply from Lake Erie to replace the supply from the Maumee River which is becoming more and more polluted, is excessively hard at most times, is suddenly variable in quality, and is generally difficult to purify.

Grand Rapids, Mich. is spending over $4,000,000 to obtain water from Lake Michigan to replace the relatively hard and polluted water from Grand River.

Albany, N. Y., not many years ago, substituted an upland supply from impounding reservoirs for a supply from the Hudson River which is subject to heavy pollution from up-stream cities, thus rendering this water unsafe and unpalatable, even though elaborately treated.

In 1930, Youngstown, Ohio abandoned the Mahoning River as a source of supply in favor of impounded upland waters, not because the flow of the Mahoning River was inadequate, but because it was polluted with sewage and industrial wastes to a degree that placed too great a burden on purification works. Furthermore, the use of the river water for cooling purposes in the steel mills raised its temperature to an objectionable degree.

Springfield, Ill., in 1935, spent upward of $3,000,000 to develop a new impounded supply on Sugar Creek to the south of the city, and has abandoned an adequate, but polluted supply from the Sangamon River.

Sandusky, Ohio is spending about $850,000 for a new water supply from Lake Erie to replace a supply from Sandusky Bay which is hard, polluted, and subject to excessive tastes and odors.

Within the past few years Little Rock, Ark. has placed in service a new water supply from an impounding reservoir, over thirty miles distant, which takes the place of water from Arkansas River which is subject to pollution, has at times an excessive salt content from oil fields, is hard, is suddenly variable in quality and is subject to disagreeable tastes and odors.

Mt. Clemens and Muskegon Heights, Mich. have abandoned highly mineralized well supplies for filtered water supplies from the Great Lakes.

## Changes Along the Great Lakes

Cities along the Great Lakes have learned from experience that neither water purification alone, nor sewage treatment alone will adequately protect their water supplies pumped from the lakes. In this connection, water purification is intended to mean filtration and chlorination in a modern plant.

Milwaukee for many years has sought to protect its water supply from Lake Michigan by building remote intakes, chlorinating the water, and treating the city's sewage. The impracticability of relying on such an arrangement has been recognized as a result of repeated epidemics of water-borne diseases, and the city has recently placed in operation a large filtration plant at a cost of about $5,000,000.

At Chicago, diversion of sewage from Lake Michigan has not been adequate to provide a satisfactory water, even though carefully chlorinated. A filter plant is now under construction at a cost of about $21,000,000 to serve the southerly section of the city, where the intakes are most subject to pollution from the Indiana cities and reversals of flow in the Calumet River, which latter have become more frequent since 1929, when diversion from the lake for sewage disposal was limited by order of the Supreme Court to but 1,500 sec.-ft.

Cleveland sought a better water supply through water purification, but increasing sewage pollution has resulted in a great program of sewage treatment.

Toronto, Canada, also sought safety in water purification, but the present heavy burden on water purification works makes improved sewage disposal imperative at an early date.

Comprehensive studies by the United States Public Health Service now under way in the Ohio River drainage area are oriented to working out a relation between sewage disposal and water supply which will insure for the area adequate water supply resources that will not place too great a burden on water purification plants.

New works for sewage treatment at Detroit and Buffalo, involving many millions of dollars, were built primarily to protect water sup-

plies taken from below these cities on the Detroit and Niagara Rivers, respectively.

## Research on Laboratory Determination Methods

The volume and character of literature that has been turned out by laboratory technicians and research men indicate clearly that they are in doubt about the reliability of laboratory determinations and the manner in which they are interpreted.

Levine, Carpenter, and Coblenz (3) made a study of 162 cultures of organisms from chlorinated water, having residuals of from 0.2 to 0.4 p.p.m., obtained from five cities. Two hundred and eighty strains were obtained by re-purification of cultures submitted. There were 196 strains of the coli-aerogenes group. Eight strains of the genus *Eberthella*, 4 of *Shigella*, and 5 of *Salmonella* were obtained, but none agreed exactly with the pathogens of these groups. A large proportion of coliform strains isolated in summer fermented standard lactose very slowly at 37°C., but produced gas readily at 30°C. These strains also produced gas readily in many newer presumptive test media, such as brilliant green bile and formate ricinoleate broth, at 37°C. While the significance of the slow fermenters at 37°C. is in doubt, the authors think that on the basis of available data they should be included in the coliform index. If so, their detection can be facilitated by lowering the temperature of incubation in the standard lactose broth to 30°C., or by substituting more selective media. In view of the isolation of non-spore forming members of the coli-aerogenes group from water containing chlorine residuals of 0.2 to 0.4 p.p.m. after contact periods of from two to four hours, the authors believe that chlorine residuals as now determined are not in themselves reliable and suggest that survivals of organisms may be due to clumping in masses that resist the action of chlorine.

Comments by H. W. Streeter (4) on standards of raw and treated water quality are interesting in the light of the findings of Levine, Carpenter, and Coblenz. After reviewing the analytical evidence in the Charleston epidemic of 1930 and 1931, the Minneapolis epidemic of 1935, the Milwaukee epidemic of 1938 and others, Streeter concludes that present accepted standards of limits of pollution for raw and treated water need not be modified, provided all factors included in the U. S. Treasury Standard, such as origin and nature of pollution, methods of purification used and subsequent handling of water are given due weight. He also recommends a freer accept-

ance of the presumptive test and avoidance of too much refinement in eliminating organisms resembling coliform organisms through confirmatory tests. Streeter also urges further study of the effectiveness of chlorination as now practiced.

## Developments in the Use of Chlorine

Promise of an answer to the question of how to obtain more reliable chlorination technique appears in the investigations of Faber and Griffin on super-chlorination for odor control. Faber (5) in a paper entitled "Super-Chlorination Practice in North America" gives a good review of this practice, noting especially the work of Houston in London and the accomplishments of Howard in Toronto. Many workers had noticed that chlorine is apt to increase tastes before destroying them. Faber related these phenomena to residual chlorine and discovered that with increasing application, the chlorine residual at first increases, then decreases and later increases again. He interpreted the drop and subsequent rise as an indication of the completion of oxidation of organic substances capable of imparting taste and odor. By plotting the successive doses of chlorine and the corresponding chlorine residuals on the same diagram and to the same scale, Faber developed a pattern which showed rises and breaks in the chlorine residual after which the chlorine residual curve would approximately parallel the chlorine application curve.

Griffin (6) supplemented these studies by similar observations and plottings on various waters. The behavior of different waters varies quite widely in the amount of chlorine required to reach a point where the chlorine-residual curve runs parallel to the chlorine-application curve but the general pattern seems to hold and seems to give a reliable index of the amount of super-chlorination required to effect complete oxidation of the odor-producing substances.

The significant thought in connection with these studies is that the initial residuals though considerably in excess of the conventional 0.2 p.p.m. are rapidly acted on by organic matter and are not reliably effective in bacterial kill. It appears further that adequate bacterial kill may not be attained until the residual curve begins to rise in a line parallel to the chlorine-application curve. Here we may have the clue to more effective chlorination and chlorine control referred to by Streeter and by Levine and his co-workers.

Schmelkes, Horning and Campbell (7) give some encouragement that a reliable potentiometric device may be worked out which will

quickly indicate chlorine residuals free from errors inherent in the ortho-tolidine test. Such an instrument would be helpful in the technique of super-chlorination and de-chlorination.

One should not jump to the conclusion that super-chlorination followed by de-chlorination will supersede the use of activated carbon for odor removal. It has not yet been demonstrated that super-chlorination is fully effective in removing all kinds of tastes and odors. Rather it is a useful device that performs the dual function of reducing many tastes and odors and producing more effective sterilization. It may find its most effective and economical use in conjunction with activated carbon, in which case the activated carbon may perform the dual function of a supplemental odor and taste removing agent and a de-chlorinating agent.

The foregoing relates primarily to attitudes toward sources of supply and laboratory investigations with rather direct reference to safety control in relation to public health. There is also tightening of control over many other operations relating to water purification. While the public health factor has never been lost sight of in the past few years, many items of design and operating technique are directed at tightening control over the economy of water purification and improving the product from points of view other than those relating to health alone.

## Studies on Coagulation

Coagulants and coagulation have been given somewhat less attention in recent discussions than these subjects received several years ago. Weak coagulation is still a problem but most operators seem to have met it with reasonable satisfaction, in their own way and according to their own local conditions.

Sodium silicate has not been extensively adopted as an aid to coagulations. It is, however, in regular use at St. Louis and will be used at the new filtration plant in Chicago. Laboratory tests at Richmond, Va. by Lordley and Smith (8) did not encourage its use at that plant. Experiments showed that silicates properly applied produce a heavier, more settleable floc than alum alone, but, except at low temperatures and turbidities, the floc had inferior adsorptive powers and the settled water was less suitable for filtration. Iron salts at low temperatures and turbidities seemed preferable. Lordley and Smith describe a unique laboratory filterability test which records time of filtration of coagulated and settled water

through filter paper under standard conditions. A floc of good appearance does not always leave a supernatant having good filterability. This test might prove of practical aid in other plants for measuring the effectiveness of coagulation and sedimentation.

At Richmond it has been observed over a number of years that, when coagulation tends to become weak, a small addition of another coagulant strengthens flocculation. If the plant happens to be running on alum, ferric chloride is added and vice versa.

Stockwell (9) gives a clear analysis of coagulation and color removal in relatively soft waters as exemplified by experience at Ottawa, Canada. Alum required is controlled by acidity and alkalinity. It increases with alkalinity and decreases with acidity. The pH value gives no indication of dosages required. Addition of alum decreases alkalinity and increases acidity. By decreasing alkalinity and increasing acidity with sulfuric acid, the alum dose may be reduced with economy. Sulfuric acid is not actually used for fear of popular objection. Most favorable color removal occurs between pH 5.1 and pH 5.4. Subsequent treatment with lime is used to correct for corrosion. Coloring matter has a chlorine demand resulting in intensification of taste. This chlorine demand is used as an index for color removal treatment. Perhaps observation of chlorine residuals in the manner proposed for super-chlorination technique might be helpful in this connection.

### Corrective Measures for Corrosion

Corrosion, its effects and its corrective measures have been given much thought in the past few years. Laboratory workers have spent much time and effort in trying to ascertain its exact causes and in studying rapid and simple methods of determining the point of stability, that is to say, the point at which water will neither dissolve nor deposit calcium carbonate. It seems to be generally agreed among the laboratory workers that in chemical corrosion, oxygen is an important factor, but that carbon dioxide is an important accessory factor and that many other chemical substances play a part. They seem to agree that stabilization with reference to calcium carbonate is effective in preventing both incrustation and corrosion, and that, if the water is adjusted so that some deposition of calcium carbonate will take place, a pipe coating will be formed which will prevent corrosion and tuberculation. The simplest form of stability indicator is an apparatus devised by Linn Enslow (10) called "The Continuous

Stability Indicator." This consists, essentially, of a tube of powdered marble through which the water to be tested passes continuously. pH determinations on influent and effluent indicate whether the water is dissolving or depositing $CaCO_3$.

Engineers appear to be less confident than the laboratory workers, of the efficacy of so-called stabilization control or corrosion control. This attitude is voiced by Wiggin (11) and Norcom (12). On the basis of unusual experience in observing flow coefficients in new, old, cleaned and uncleaned pipe, Wiggin concludes that corrosion is far more prevalent than generally supposed even in hard waters. Even stabilized waters show corrosive effects. He points out that most of the claims for the benefits of correction of corrosion and deposition of protective coatings are not fortified by actual observations of changes in discharge coefficients. Norcom refers to the soft mushy character of deposited coating and notes active tuberculation and corrosion under these coatings.

Few data are as yet available on the effects of silicates and phosphates on prevention of corrosion. Claims made for hexametaphosphate in preventing both corrosion and deposition are interesting and encouraging but final conclusions must await further and more adequate observations.

Engineers feel more confidence in good protective pipe coating than in chemical treatment of the water. Cement linings, concrete pressure pipe and improved bituminous linings meet these requirements to a large extent. More systematic observations on pipe-flow coefficients to ascertain the effects of age on various types of linings and various kinds of chemical treatment are greatly needed. Such data will do much toward tightening control over the carrying capacity of pipe lines and distribution systems with resultant great conservation of investment.

## Water Softening Projects

Water softening presents some active problems in water purification as exemplified by two large installations, namely at Minneapolis (13) with a capacity of about 120,000,000 gallons per day, and in California for the Metropolitan Water District of Southern California (14) with a capacity of 100,000,000 gallons per day initial capacity. Two other large installations, one at Chicago (15, 16) and the other at Toledo (17) are designed for moderate softening with lime only. The lime will also act as an aid to coagulation.

## Sludge Disposal in Southern California

Sludge disposal in these large installations becomes a serious problem. In Southern California, where there are no nearby large streams, the design of the works is to some extent oriented about sludge disposal. By using lime treatment for removing calcium carbonate hardness only, and by using zeolite for removing magnesium salts and non-carbonate hardness, a relatively pure calcium carbonate sludge can be obtained. Also the total volume of sludge will be held at a minimum. At a later period the calcium sludge will be de-watered on vacuum filters calcined and re-used. The carbon dioxide generated in the lime kiln will be utilized for stabilizing monocarbonates. For the present sludge will be lagooned on nearby low value land.

Because the Colorado River supply must be pumped through an elevation of over 1600 feet, every effort will be made to keep waste water at a minimum. Filter wash water will be settled and reclaimed. A synthetic zeolite of high exchange value with upward flow is expected to reduce waste brine and wash water to a minimum. The total water to be wasted will be less than 1.4 per cent of that treated. To prevent ground water contamination the spent brine must be piped to the ocean over thirty miles away but this is considered less expensive than handling a larger volume of sludge unsuitable for re-use that would be produced by the lime-soda process.

## Minneapolis and Chicago Sludge Disposal Problems

The Minneapolis installation comprises the largest installation of Spaulding precipitators yet attempted. These involve some interesting design and construction problems. While no present provision is included for sludge reclamation, it is recognized that such large quantities of sludge may prove troublesome in the Mississippi River at low water and therefore space is provided for later installation of sludge recovery equipment.

At Chicago the problem of sludge disposal is not yet worked out. Consideration is being given to three methods or combinations of these methods namely: (1) discharge at a point in the lake about 2000 feet from shore; (2) de-watering on vacuum filters and removal by barging into the lake (in summer) or hauling away in trucks (in winter); and (3) discharge into the sewers of the sanitary district.

All have objections. Piping into the lake may result in white water being washed onto nearby beaches under certain wind conditions. Accumulations in the lake bottom may interfere with navigation and require periodic dredging. Discharge through a pipe into the lake is the cheapest method and, except when beaches are affected, is the most practicable and satisfactory. De-watering and removal in scows and trucks is expensive. Favorable localities for winter dumping are scarce. The sanitary district objects to the discharge of large volumes of lime sludge into its sewers because of the added burden on sewage treatment works. Perhaps a combination method may be worked out involving a normal discharge into the lake through a pipe line and emergency discharge into the sanitary district sewers in summer during the short periods of south east winds, the only ones likely to affect beaches.

## Sludge Reclamation and Re-Use of Lime

Sludge reclamation in connection with lime softening has not been attempted in municipal practice, principally because of high turbidities and changeable character of the raw water. Furthermore the design of existing plants is not adapted to segregation of a relatively pure and clean calcium carbonate sludge. In small plants, using ground waters of more or less uniform character, the economies that can be effected may not be sufficient to justify the required plant and operating costs. On the other hand, recovery of lime in some industries, for example the beet sugar industry, has been practiced economically.

The question of reclamation and re-use of lime in water softening has been placed on a much firmer basis for application to municipal water softening plants by Aultman (18) who, on behalf of the Metropolitan Water District of Southern California, conducted plant-scale experiments at the Boulder City water works, using the Estabrook process. The Hoover process was also considered. These two processes differ in the arrangement of the softening process for segregation of relatively pure calcium carbonate sludge free from magnesium. Parenthetically, it is interesting to note that vacuum filters used to de-water the lime sludge and continuous kilns of the Nichols-Herreshoff type for calcining the de-watered sludge constitute the same type of equipment that has recently had wide application in the de-watering and incineration of sewage sludge.

## Use of Ion-Exchange Materials

Carbonaceous zeolites, organic ion-exchange material, or cation and anion removers, as they are variously called, have attracted much attention among water works men because of their capacity to demineralize waters. Cation removers are regenerated with acid and anion removers are regenerated with sodium hydroxide. Goudey (19) has pointed out the advantages of removing troublesome amounts of sodium carbonates, sulfates and chlorides from water used for municipal supply or for irrigation. He mentions, also, the removal of dangerous amounts of fluorine and boron. His paper describes a series of laboratory experiments with commercial organic ion-exchange materials to illustrate their behavior. He estimates that their use for public water supply purposes may not be too costly, especially with economies and improvements that may be expected to follow a rising demand for public water supply purposes. Cation and anion removers are already established in treating waters where relatively high treatment costs are justifiable. In discussing Goudey's paper Applebaum predicts early improved and more reliable methods of removing fluorides and silicates.

Associated with water softening is carbonation. Scott (20) appears to have the answer to the operators prayer for a better method of recarbonating softened water through the development of submerged combustion at Oklahoma City. This work was carried out in cooperation with the Ozark Chemical Company which had developed an under-water burner for evaporating sodium sulfate. Scott described the apparatus as simple, reliable, economical and unusually effective. It is limited to gas as a fuel and this may limit the economy of the process.

## Sulfur Dioxide and Aqueous Ammonia

Sulfur dioxide is finding greater use in water supply practice, a trend which is encouraged by its availability in convenient cylinders at moderate price and by the possibility of applying it by means of available types of chlorinators. Its use for de-chlorination has been mentioned. It may also be used for cleaning sand in filters.

Aqueous ammonia is gaining favor in preference to anhydrous ammonia and ammonium sulfate for use in combination with chlorine to form chloramines. It represents a definite, though not very

great, economy as compared to anhydrous ammonia and represents a greater economy as compared to ammonium sulfate. It appears to involve fewer operating difficulties, less refrigeration effects than in the case of anhydrous ammonia and less messiness of handling and storing than in the case of ammonium sulfate.

Aqua ammonia has been in use at Atlantic City since early in 1939. It has recently been adopted by Lauter at the Dalecarlia filter plant in Washington D. C. and is reported as giving good results and good economy.

A comparison of estimated costs for the several forms of ammonia for use at the new 80,000,000 gallon per day filter plant at Toledo, predicated on the use of 50,000 lb. per year as anhydrous ammonia, is given as follows:

| | Installation Cost | Annual Operating Cost |
|---|---|---|
| Anhydrous ammonia | $15,200 | $2,500 |
| Aqua ammonia | 10,700 | 2,200 |
| Ammonium sulfate | 7,500 | 3,500 |

## Studies on Flocculation

Flocculation, that is to say the practice of slowly stirring, for a prolonged period, the water containing coagulant prior to sedimentation, is now generally employed. Thirty minutes stirring is more or less accepted as a minimum period and anything beyond sixty minutes is not regarded as economically justifiable. Forty-five minutes represents a reasonable mean and some of the newer larger plants are designed on this basis. Vertical shaft stirring devices in separate chambers, as at Hammond, Indiana, and elsewhere, give good results and permit a good plant layout for capacities up to about 30,000,000 gallons per day. The paddle-wheel type of stirring device is more adaptable to larger capacities. Tests by Baylis at the Chicago experimental filtration plant indicated that an arrangement of wheels with shafts at right angles to the flow and with hanging baffles between do not give as good results as vertical-shaft stirring devices in chambers, or as good as horizontal-shaft stirring devices with the water progressing longitudinally of the wheels. The new Chicago and Toledo filtration plants have the paddle-wheel type of stirring mechanisms arranged in passage ways or chambers so that the water follows longitudinally along the wheels with a helicoidal motion.

## Design of Sedimentation Basins

Though design of sedimentation basins is the most controversial element in a filtration plant and has the least scientific basis, there have been no marked changes in recent years. There is noticeable a tendency to use somewhat smaller basins on the theory that better control of coagulation makes this permissible. Also a tendency to equip sedimentation basins with mechanisms for continuous removal of sludge has been noted. Such devices are particularly helpful where lime is used to assist coagulation or for partial softening. Avoidance of large sludge accumulations makes the full capacity of the basin available for sedimentation, which fact further justifies somewhat smaller basins. A nominal retention period of $2\frac{1}{2}$ hr. is to be used in the sedimentation basins at Chicago, 3 hr. at Toledo and 4 hr. have been provided at Milwaukee.

The role of mixing and sedimentation units of the "precipitator" and "accelerator" class is not yet clear in municipal practice, especially in relation to waters that must be clarified as well as softened. At Springfield, Ill., precipitators continue to operate successfully on the more or less turbid waters from an impounding reservoir. Experience with the large scale installation at Minneapolis, which will treat river water of varying quality, should be enlightening.

In three important filtration plants, Fort Wayne, Milwaukee and Chicago, two-story sedimentation tanks have been employed. This type of construction was not adopted because of expected superiority of performance of the two-story tanks as compared with one-story tanks but for economy. In each case the space required for sedimentation was made expensive either by extensive piling (Fort Wayne) or by reclamation from Lake Michigan (Chicago and Milwaukee).

In large installations the trend is toward filter units of large capacity in the interests of economical construction. Units with a nominal capacity of six million gallons per day based on a rate of filtration of two gallons per square foot per minute are the largest attempted to date, and are exemplified in the recently completed Victoria Park Plant at Toronto and the Milwaukee plant. Larger capacities involve some complications in the design of inlet and outlet arrangements and difficulties in obtaining even distribution of wash water. Economy is not always the controlling item in deciding on the size of filter units. A sufficient number of units to prevent too large a por-

tion of the total capacity being out of service at one time is important. Arriving at a satisfactory general arrangement sometimes dictates the number and size of filter units. Large units generally require a channel, for influent and soiled wash water, extending longitudinally along the center of the unit. Thus, in effect, the unit is divided into two filters with but single control of all connections. This arrangement is criticised by some operators because identical conditions cannot be created or maintained in each side of the unit, and hence the two sides may perform differently while there is little that the operator can do to detect or correct such unequal performance.

At Toledo this situation has been met by having separate effluent and separate wash water control for the two halves of each unit. The influent and drain connection remain common to the two halves. On comparison it was found that this arrangement did not add to the cost but represented a small economy by reason of the reduction in diameter of the main wash water pipe.

## Various Filter Bottoms

The slat-type of filter bottom has been found unsatisfactory at the Dalecarlia Filter Plant in Washington D. C. and is now being replaced in all the filters with a grid-type system using perforated transite pipe.

Wheeler bottoms are coming into renewed favor, especially in Ohio where there has been long, and on the whole, satisfactory experience with them, notably at Akron. Patents on this type of bottom have run out and they may now be purchased on a competitive basis. The false bottom arrangement makes Wheeler bottoms adaptable to large units and the absence of any metal parts removes problems of corrosion. Wheeler bottoms are being installed at Toledo and at the new filtration plant at Sandusky, Ohio.

Confidence is growing in the use of porous plate filter bottoms as manufactured by the Carborundun Company. The most convincing evidence comes from Campion (21), who reports the successful use of porous plates, in Filter No. 4 of the Grand Rapids filtration and softening plant, since 1936 and this notwithstanding the fact that the filter handles a lime treated water and that the sand in the filter is heavily incrusted. Stevens (21) describes a successful rehabilitation of old clogged filters at Flat Rock, Mich., by substituting porous plates for a grid-pipe system. This gained the incidental advantage of greater freeboard between the surface of the sand and the crest of

the wash water overflow troughs through elimination of the gravel layer, thus permitting more effective filter washing.

### Filter Sand Problems and Studies

Filter sand can at any time arouse a good discussion. The problem of how to choose and care for filter sand flares up with new intensity from time to time, and seems about to flare up again. It has been brewing between the coarse sand proponents and the fine sand proponents for several years, but has recently been given impetus by Riddick (22) in a paper describing experience with filter sand in three filter plants. A committee has been created this year by the Water Purification Division of the A. W. W. A. to review and report upon the filter sand problem.

In 1890, Hazen at the Lawrence Experiment Station of the Massachusetts State Board of Health devised an accurate method for examining filter sand and invented the terms effective size and uniformity coefficient. No more accurate method of examining filter sand has been devised since. There has been no criticism of Hazen's method of sieve analysis, except that the calibration of sieves, as worked out by him, is too laborious. To this day the tolerances permitted in commercial testing sieves are too great to permit sufficiently accurate work unless the sieves are calibrated by the method Hazen devised.

There has been interminable discussion of the suitability and applicability of the terms "effective size" and "uniformity coefficient." Curiously, Hazen himself never placed much emphasis on these terms but did emphasize the importance of critical examination of the plotted curve of calibrated sieve separations.

Fuller, in 1897, as a result of his experiments at Louisville on rapid sand filters recommended a 30-inch thickness of sand, an effective size of about 0.35 mm. and a uniformity coefficient of not over 1.7. This remained as a standard of practice for about twenty-five years.

From 1918 to 1924 there was much agitation in favor of using standard sieves calibrated photographically by the U. S. Bureau of Standards and expressing the analysis in terms of number of meshes to the inch. A committee of the A. W. W. A. concluded that standard sieves were not made with sufficient accuracy and that until reduced tolerances could be obtained it was preferable to continue with the Hazen procedure.

Until 1927, the opinion was held generally that some gelatinous

coating of sand grains was desirable for effective filtration. In about 1923, Baylis began the study of filter sand and noted excessive clogging and cracking of filter beds as a result of the presence of too much organic matter in the sand.

In 1927, Herring and Hulbert, working in Detroit, started experiments to evaluate sedimentation phenomena. They discovered that the behavior of the filters constituted a troublesome variable in their experiments. To eliminate this variable they sought means for thorough cleaning of the filter sand. This they accomplished by rates of washing much higher than previously attempted. They discovered that clean sand gave better filter results than coated sand. They also found that coarse sand of about 0.6 mm. effective size was more easily cleaned by the high rates of filter wash. This work effected a marked change in thought and practice regarding the selection and use of filter sand.

High rates of under-wash did not effectively remove mud balls, the presence of which was accentuated with the demand for cleanly washed sand. Some of the older members will recall that in the early days of mechanical filter practice, when revolving surface rakes were employed during washing, there was little trouble from mud balls or other dirty sand phenomena.

Baylis, from 1925 to 1935, successfully revived surface agitation by means of a surface wash, a device that had been used experimentally by DeBerard and Pearse in 1910. A combination of underwash and surface wash is now rapidly becoming standard practice and is embodied in the large new plants at Chicago, Milwaukee and Toledo.

A committee on filtering materials of the American Society of Civil Engineers, which remained in existence from 1926 to 1935, made some valuable contributions to thought on sand for water filters. Experiments conducted at Baltimore by Armstrong, a member of the committee, showed that removal of suspended matter was a function of the size of sand grain and the depth of the sand bed, and that lengths of filter runs between washings are greater with coarse sands up to about 0.8 mm. in size and 30 inches in depth without reducing the effectiveness of removal. Though suspected for years, the concept is now proved that the filter layer works throughout its depth and not at the top only, that a practically uniform sand grain may be desirable and that the selection of grain size involves an economical balance between depth of sand and length of run (and

hence wash water required), other things being equal. Other things are not always equal, as for example the effectiveness of coagulation and sedimentation. Better control over this process than now obtains may permit some concession to larger sand grains.

This newer concept of the behavior of filter sand or other filtering media combined with improved coagulation and sedimentation, improved means for observing minute residual suspended matter in filtered water, improved sterilization and better control over the condition of the filtering medium, point the way toward a revised evaluation of sieve analysis, grain size and uniformity, shape of grain, composition of filtering medium and thickness of filter bed.

There will always be active problems in water purification. Whereas a generation ago greatest concern was with the relative safety of slow sand filters and rapid sand filters and the practicability of obtaining 98 per cent bacterial removal instead of 97 per cent, we are now concerned with better conservation of water supply resources, with refinements in treatment and tightening of control to a point where the public can, without fail, be supplied with a treated water that meets every aesthetic and public health requirement.

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# Control of Iron and Sulfur Organisms by Super-Chlorination and De-Chlorination

*By Louis J. Alexander*

THE iron and sulfur groups of bacterial organisms found in domestic water supplies, and the odors and tastes produced by them, can be successfully controlled by super-chlorination and de-chlorination. This simple and relatively cheap method of control deserves serious consideration by those whose water supplies are contaminated with iron and sulfur organisms. The treatment is successful up to the point where the concentration of these organisms becomes so great that sludges, deposited in pump forebays, begin to pass to the distribution system; then it becomes necessary to resort to coagulation and filtration as additional treatment.

To describe the success of super-chlorination and de-chlorination as practiced in Southern California at seven plants of the Southern California Water Company, it is advisable to give a brief description of the geologic formations and the peculiar characteristics of the underground reservoirs from which much of the water supply of Southern California is obtained.

The coastal plain of Southern California is nearly rectangular in shape. In a northeasterly-southwesterly direction from the mountains to the ocean, it is about fifty miles wide. The axis, through the Puente Hills, which bisects the plain in a northwesterly-southeasterly direction is about ninety miles long. Roughly, there are about 2,200 square miles of habitable area on the coastal plain, the western 40 per cent of which is termed the metropolitan area.

The surface topography indicates that there are five water bearing regions. Four of these constitute the upper regions, lying between the Puente Hills and the mountains. The fifth is the area between

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the Puente Hills and the ocean. Underlying these five regions is a maze of rock subsurface structures, overlaid by loose unconsolidated clays, sands, and gravels, which define some thirty odd major underground reservoirs (1). In addition, there are as many minor reservoirs.

The subsurface structures in the four upper regions have been fairly well defined by the water levels in wells drilled through the unconsolidated alluvium. It is not uncommon in these regions to find, in adjacent underground reservoirs, a difference of fifty or one hundred feet in the elevation of the water tables.

In the lower coastal region the reservoirs are less definitely defined. Earthquake faults and oil anticlines define several, but usually it is possible to define them only through the quality and character of the water extracted from the reservoir. One would not expect this because the waters recharging these underground basins in the lower region are from the four rivers of the coastal plain, and from rain falling on the valley floor. The waters of these four rivers, both surface and subsurface, as they enter the lower coastal plain are quite similar in chemical character. It is well to call attention to the fact that these so-called rivers are in reality subsurface streams except in the rainy season when flood conditions exist.

In percolating underground from one reservoir to another, the waters in the lower coastal plain change both chemically and bacteriologically. These changes are due to the formations through which the underground waters pass, to contamination by industrial wastes, to leaching by rain and irrigation waters, and to the infiltration of sewage wastes. Further, some of the alluvium of the lower coastal plain was probably laid down on top of dense vegetation. This organic matter has undoubtedly become the food of untold numbers of bacteria (not pathogenic) which have been drawn into the underground reservoirs by percolating waters. Where wells are drilled into these underground reservoirs of water contaminated with bacterial organisms, it follows that the water pumped to the surface will contain these organisms. As time has passed, water levels in the reservoirs have been lowered until in many instances pumping is now from or near the bottom of the basin, and consequently from the strata most highly contaminated with decaying organic matter. This may be illustrated by the use of the old-fashioned watering trough: the top waters might be relatively free from bacteria or organic matter, but as the water receded in the trough, all forms of

bacteria would be present in the accumulated sludge in the bottom. This, of course, is a homely illustration, but it is comparable to what is happening in the underground reservoirs.

### A Typical Example

An example is the history of the Sentney Pumping Plant. In 1904, Mendenhall (2) of the United States Geological Survey made a hydrographic survey of an agricultural area which has since become the site of Culver City. The underlying gravels in this area, at that time, were found to contain water of sufficient artesian pressure to raise the water to considerable heights above the surface of the ground. In 1923 this artesian area still existed and water flowed into the forebay at the Sentney Plant. As time has passed, the water table has been lowered by excessive pumping until the pumping water level is at present 180 feet below the surface. In 1923 the water produced from these wells at the Sentney Plant of the Southern California Water Company was of the finest character found anywhere in Southern California. It had slightly over 150 parts per million of hardness, and was absolutely free from carbon dioxide, hydrogen sulfide, methane, or bacterial contamination. By 1931, when the pumping level was 140 feet below the surface, there appeared a slimy growth on the walls of the concrete forebay. Unfortunately, at that time relatively little was known about the control of these organisms. In 1932 intensive efforts were made to free the water from the slimes and resulting odors and tastes produced by them. With further recession of the water levels, the concentration of contamination had increased to such an extent that by 1936, to control the odors and tastes, and to remove the organic matter completely from the water, it was necessary to install coagulation and sand filtration.

The Sentney Plant has been used in the foregoing illustration because it is somewhat typical, and because most of the experimental work in the control of the iron and sulfur organisms was done at this plant. Further, it illustrates the progressive stages of contamination through which many of the lower coastal reservoirs have passed, or may yet pass.

Following the experimental work step by step will show how the control of these organisms by super-chlorination and de-chlorination was effected. As mentioned previously, in 1931 formation of slimes on the concrete walls of the forebay was first noticed. The slimes were caused by iron and sulfur bacteria, the occurrence and descrip-

tion of which have been adequately covered by Brown (3). When the slimes first appeared, there was apparently no odor or taste present in this water in the forebay. Later, considerable spoilage of the water in the pipe lines developed. Hydrogen sulfide was evident at dead ends, and consumers complained about bad odors and tastes in their water. A program of experimental work and limited plant scale treatment was laid out, inspired by papers by Hale (4), Howard (5), and Ruth (6). The first chlorinator was installed in 1931. Dosage was very small at first, but was increased from time to time until one part per million produced a chlorophenol taste. A larger dosage was necessary, but the chlorophenol taste had to be overcome. Ammonia was used in an attempt to accomplish this.

## Treatment by Chlorine Alone

Troubles then began in earnest and complaints kept the switchboard hot. The formation of hydrogen sulfide at the dead ends increased. Slimes accumulated in the forebay to such a degree that weekly cleaning was required. The growth in the pipe lines was so great that these slimes began to appear at consumers' taps. A program of intensive flushing was instituted, but the formation of the slimes and their accumulation on pipe walls was more rapid than could be flushed from the mains. Ammonia proved to be unsatisfactory because the slimes continued to increase rather than decrease. After some weeks of intensive effort to find the right proportions of ammonia and chlorine, and the right points of application, it was decided to revert to chlorine without ammonia. The troubles seemed to lessen but it was apparent that additional treatment was necessary. The reason for the failure of ammonia has since been traced to what is thought to be a group of nitrogen bacteria. It may be well to call attention to the fact that there never has been any indication of coliform organisms at the plant.

The experiments which were being carried out during this period indicated that activated carbon, following chlorination, would remove the odors and tastes. It was thought that chlorine would kill the organisms and that the activated carbon would remove the odors and tastes. Any excess chlorine would also be removed, when and if the carbon was used, and it seemed that ever increasing amounts of chlorine would be necessary. Finally a rate of feed which was maximum for the chlorine equipment then in operation was reached. As was learned later, dosing proceeded at a rate which was on the

first rise of the curve shown as Fig. 4 of Faber's paper on superchlorination practice (7).

## Installation of Large Activated Carbon Filters

On the strength of the experiments, a battery of three activated carbon filters was purchased and installed. At that time it was the largest installation of its kind in the country. On July 4, 1933, this battery of three pressure filters, charged with activated carbon for removing taste and odor from water, was placed in operation. There was a sigh of relief as the 50 or 60 complaints a day were entirely eliminated. Then, as so often happens, it was felt that the ultimate solution had been achieved, but in November of the same year, complaints began to come in even more rapidly than during the period prior to July 4. The activated carbon filters were investigated carefully, and it was found that the granules of carbon were cemented together by a mass of gelatinous material. The first reaction was that this seemed to be an expensive treatment as there was $2,800 worth of carbon which had been effective for only five months. It indicated that practice did not match the experimental data. The troubles and experiences were described in detail by Harnish (8).

Upon the recommendation of the chemists of the International Filter Company, the carbon was then treated with caustic soda and hydrochloric acid, but the expected removal of gelatinous material was not accomplished. The process was repeated and the carbon scrubbed by injection of compressed air while it was in the caustic soda solution. These drastic measures accomplished the desired results and the carbon again functioned properly.

Air wash facilities were then installed for regular washings. Instead of being washed on loss of head, the carbon was washed with air and water regularly at 24-hour intervals regardless of how much or how little water had passed through the filter. The harsh treatment seemed to prevent the accumulation of organic matter within the carbon beds, but it was very destructive to the structure of the carbon granules. To remove the excessive amount of organic matter, and to protect the carbon granules, it was found necessary to construct a clarification plant with sand filters ahead of the carbon filters. The clarification treatment plant was placed in operation in 1936.

All during this period, in the attempt to control the increasing growth of iron and sulfur organisms, the dosage of chlorine was in-

creased periodically. Later, in plotting the results, a curve similar to Faber's (7) was again obtained. The method for determining dosage necessary for super-chlorination, however, was different from Faber's in that it took into consideration the detention period of the plant. Samples of the raw water were taken and chlorine added until a "stable residual" was obtained. A "stable residual" (9) may be described as that which is found upon taking two residuals of the same sample, thirty minutes apart, and obtaining the same result. If sufficient chlorine is added to the water to complete all oxidizing processes in the time allowed for detention within the plant, then the residual will remain nearly constant. Repeated observations of plant practice show that a "stable residual" will persist for several hours (ten or more) in relatively large storage tanks. It must be borne in mind, however, that it is only in a concrete reservoir that a "stable residual" will persist for long periods.

## De-Chlorination

It was believed that all odors and tastes appearing in well waters were produced by oxidizable compounds. Thus, if oxidation were carried to completion, these odors and tastes would cease to exist, and following super-chlorination it would be necessary to remove only the excess chlorine to obtain a water both odorless and tasteless. If this were true, any agent which would accomplish de-chlorination would be applicable to the process. So far, experience has proved this to be a fact.

In addition to activated carbon, which acts as an adsorptive agent, there are several chemicals which react with chlorine to produce a tasteless product. The choice of the proper agent for de-chlorination rests, then, with economical considerations, and the physical conditions of the plant. In plant practice experience has been limited to activated carbon and sulfur dioxide. There are advantages and limitations for each.

Activated carbon has one advantage which none of the other agents possess. If there is a slight failure of the chlorination equipment, and super-chlorination has not been reached, the carbon will remove certain of the odors and tastes. Too much reliance upon this, however, leads to the failure of the carbon, as previously described, and the accumulation of organic matter within and around the carbon granules. Some of the iron and sulfur organisms are so minute in

size that they are not retained on sand filters. They will pass through ordinary sand filters if the oxidation and coagulation processes are not complete. Carbon possesses another advantage, and that is its ability to de-chlorinate variable rates of flow.

Sulfur dioxide is economically fed only through constant rate feed machines, and its use is limited to points of injection at low pressures such as the suction side of booster pumps or open channels. Another objection to sulfur dioxide is that feed machines and sulfur dioxide cylinders must be kept in rooms where the temperature is thermostatically controlled. The practice is to maintain constant temperatures of 93°F. At such temperatures the sulfur dioxide may be fed satisfactorily by means of chlorinating equipment.

Sodium bi-sulfite has been used (Faber) for de-chlorination. By the use of such machines as the Proportioneer's Pump, this agent can be fed under pressure. Such an installation is planned at the Sentney Plant on a bypass line around the activated carbon filters.

When de-chlorination is by chemical reaction, the required dosage is relatively easy to determine. For granular activated carbon, however, the problem is somewhat different. At the Sentney Plant the filter capacity for the reduction of odors and tastes was based on one cubic foot of carbon for each gallon per minute of flow. For de-chlorination this capacity may safely be increased to $1\frac{1}{2}$ or 2 g.p.m. per cu.ft. There is as yet no established "law" but at such a rate the filters at Culver City have been operating satisfactorily for over four years. For short periods higher rates have been used, but it has been assumed that a rate of 2 g.p.m. per cu.ft. of carbon should not be exceeded. This assumption remains to be proven.

So far in this paper the Sentney Plant has been the only one mentioned in describing the control of odors and tastes produced by the iron and sulfur organisms. Mr. Faber (7) mentioned six plants in the vicinity of Los Angeles, all operated by the Southern California Water Company. A brief description of the seven plants, as they are operated by the company today, will explain the treatment necessary for each plant. They will be considered in the order in which odors and tastes produced by iron and sulfur organisms first required control.

*Sentney Plant (1933):* Aeration by compressed air, super-chlorination, coagulation with ferric chloride, sedimentation, sand filtration, de-chlorination with activated carbon. The plant capacity is being

increased (1940) beyond the desirable limits for the carbon, and secondary de-chlorination on the bypass of the carbon filters will be accomplished by means of sodium bi-sulfite.

*Manning Plant (1933):* Aeration by cascading the water over baffles, super-chlorination, coagulation by ferrisul, sedimentation, sand filtration, de-chlorination by final aeration. The water at this plant contains about 1.0 p.p.m. manganese. This is sufficient to coat the sand with oxides of manganese and the filter has the appearance of an anthrafilt layer.

*Charnock Plant (1934):* Additional aeration is being provided this year (1940) and will be accomplished by means of a vacuum created on an air inlet line. Super-chlorination and de-chlorination with sulfur dioxide are practised. Contamination has started to increase at this plant and further treatment will be necessary in the near future.

*Truro Plant (1934):* The original wells drilled in 1931 showed evidence of hydrogen sulfide. Treatment is by aeration by compressed air, ferric chloride coagulation, super-chlorination, sedimentation, sand filtration, de-chlorination with sulfur dioxide.

*Sepulveda Plant (1935):* Super-chlorination and de-chlorination.

*Rosecrans Plant (1937):* Aeration by compressed air, super-chlorination, and de-chlorination with sulfur dioxide.

*Normandie Plant (1938):* Aeration by cascade through screens, super-chlorination, and de-chlorination with sulfur dioxide.

## Automatic Operation of All Plants

These plants are all operated automatically. The method of plant control for boosters, well pumps, and chemical feed equipment was described by Curry (10). Because of this automatic feature of plant operation it was necessary to develop special chlorinating equipment. This equipment has been built, using Wallace & Tiernan apparatus. At each plant the dosage of chlorine is determined by the pump capacity and the amount of contamination present in each well. Thus, when a well pump starts, the chlorinator, through the use of a chlorine valve, injects the proper dosage. Curry (10) described the automatic operation of the plant as a whole, but a description of the chlorine and sulfur dioxide equipment is in order.

A manifold collects the feed lines from one or more chlorine cylinders. From the first to the second manifold is a brass transmission line. Connected to the second manifold are one or more chlorine

shut-off valves; each of these valves feeds one compensator which is set at the exact dosage required for the particular well. Beyond the compensators, the chlorine is collected by a common line leading to an orifice meter and from this the chlorine passes through a back pressure valve to the water injector.

Sulfur dioxide machines are similar to chlorinators except that the water injector is omitted and sulfur dioxide is fed as a gas.

One of the most difficult problems was to develop a chlorine control valve which would open and close automatically on electrical impulse when the well pump started. After a thorough trial of every commercial valve available, a chlorine shut-off valve was developed, and has functioned satisfactorily for over two years. This valve not only operates satisfactorily for chlorine, but also for sulfur dioxide, so that now electrically controlled valves for both super-chlorination and de-chlorination are being used.

Comments on the control of iron and sulfur organisms cannot be complete without the mention of one plant which is controlling these organisms by lime softening. Carl Wilson (11), in determining the treatment for the softening plant recently constructed by the city of El Segundo, made use of the fact that a very high pH, obtained by lime softening, would act as a sterilizing agent. This process has proved successful.

## Conclusion

Experiences indicate that iron and sulfur organisms, with their resulting odors and tastes, can be controlled. It must not be inferred from this discussion, however, that all waters in the lower coastal plain of Southern California are contaminated by iron and sulfur organisms, nor should it be inferred that all water supplies in which contamination appears are being controlled. The Southern California Water Company alone operates the water systems in about thirty communities, seventeen of which are on the lower coastal plain. Of these, the Venice, Culver City, Lennox, Lawndale and Normandie systems overlie seven major or minor underground reservoirs contaminated with iron and sulfur organisms. In addition to these seven, there are approximately twenty basins underlying municipalities whose water supplies are contaminated. With the exception of these plants, and the plant at El Segundo, no other water supplies have been successfully treated up to the present time.

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# Super-Chlorination at Ottumwa, Iowa

## *By Horace A. Brown*

OTTUMWA, Iowa, with an estimated population of 35,000 for 1940, is located on the Des Moines River 107 miles, via river, below the sewer outlets of the state capitol, Des Moines (estimated population for 1940, 140,000). Des Moines has a fair sized meat packing plant, one or more rendering plants and numerous other industries, the wastes from which, together with all of the domestic sewage of the city, are discharged directly into the river without treatment of any kind. Ottumwa is the only city below Des Moines that takes its raw water supply directly from the river.

During last fall and winter the river was at a record breaking low flow, the total volume coming into Des Moines, according to U. S. Geological Survey records, was 18 million gallons per day. From this total the Des Moines water works was pumping 6 million gallons per day to the sand fields below which the Des Moines infiltration galleries are located. The amount of water being used in Des Moines was about 14 million gallons per day and the bulk of it was being returned to the river as raw sewage, giving a total flow, leaving the city, of 26 million gallons per day—14, sewage; and 12, natural flow of river.

Real winter started on December 26, at which time the raw water was carrying between 15 and 16 p.p.m. of dissolved oxygen and 10 to 12 p.p.m. of carbon dioxide. By the morning of January 19, the dissolved oxygen had dropped to a trace, disappearing entirely during the day. The turbidity at that time was 30 p.p.m. The river had a heavy coating of ice, 15 to 18 inches thick, and a blanket of snow, forming a completely closed conduit leading directly from the Des Moines sewers to the Ottumwa intake. Simultaneously with the disappearance of the dissolved oxygen from the raw water, dead and

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A paper presented on April 23, 1940, at the Kansas City Convention by Horace A. Brown, Superintendent, Ottumwa Water Works, Ottumwa, Iowa.

dying fish in large numbers began to appear in the intake and bad tastes and odors developed rapidly.

The first attempt at solution of the problem was pre-chlorination, applying to the raw water 1 p.p.m. of chlorine (the maximum the chlorinator could handle normally) followed by increasingly large doses of activated carbon. This treatment relieved the situation for a day or so, but did not effect a cure. Larger equipment was ordered, and pending its arrival certain changes in equipment were effected to increase the feeding capacity to 3 p.p.m. of chlorine in the suction of the raw water pumps. Again a short period of relief was given but the raw water tastes and odors grew stronger daily.

On February 4, a new vacuum-type chlorinator was delivered. Its maximum capacity was 720 lb. of chlorine per day, which at the rate of pumpage (8 m.g.d.) made it possible to feed an additional 10.8 p.p.m., or a total, applied with both machines, of 13.8 p.p.m. It was hoped that the new capacity would enable super-chlorination. The additional 10.8 p.p.m. of chlorine was first applied to the clarified and softened water entering the secondary basin, the use of activated carbon being discontinued. After a three-day trial in this manner, the point of application was changed to the treated water entering the flocculator. Softening treatment then consisted of 20 g.p.g. lime and 6 g.p.g. soda ash. De-chlorination of the filtered water was being accomplished with sodium bisulfite applied to the filter effluent, about 4 p.p.m. of residual chlorine coming through the filters. This treatment was very unsatisfactory as it left a threshold odor of 40 to 50. The raw water at this time was received with a threshold odor of about 600 as determined by engineers from the staff of the State Board of Health.

The next move was to change the point of de-chlorination to the outlet of the primary settling basin and to resume the application of activated carbon at the entrance to the first re-carbonation basin. Doses of carbon were rapidly increased until 400 lb. per million gallons were being applied. Immediately carbon began coming through the filters, but this was stopped by adding about 1 g.p.g. alum in the final re-carbonation basin. The alum applied at this point yielded a good floc which trapped the carbon and kept it from penetrating the filters. The results were still so poor that the threshold odor in the filtered water could not be brought below 30. The location of the new chlorinator was then changed so that all the chlorine, 13.8 p.p.m., could be applied to the suction of the raw water

pumps, leaving the rest of the treatment as before. Only a very slight increase in benefits was noticeable.

The citizens of Ottumwa had by this time practically abandoned the water for cooking and drinking, as the terrible odor and taste of urea and ammonia made such usage almost impossible.

Through the newspapers, the public was kept fully informed as to the reason for the trouble and the efforts being made to effect a remedy. People were very considerate, only a very small number of objections being made. Wells, cisterns and bottled water were in great demand. Repeated warnings were issued to the public to beware of such sources until laboratory tests could be made to determine their safety. The effectiveness of such warning is borne out by the fact that not a single case of dysentary or other water-borne disease was reported.

## Break-Point Established

On February 25, some new tests were started to find out where the break-point, if any, in the residual chlorine applied would come. A series of 16 jars was set out. Into each of them was put 500 ml. of raw water, and doses of chlorine were applied, beginning at 2 p.p.m. and increasing in each successive jar by 2 p.p.m. The treated samples were allowed to stand for 30 minutes, then the residual chlorine was determined by the starch-iodide process, titrating with sodium thiosulfate, and recording the results. The jars were then dumped and the process repeated, beginning where the last series left off. This process was continued until a radically different color was noted in the last jar of the last series. This jar had been treated with 112 p.p.m. of chlorine. The titration showed that this specimen had a chlorine residual of only 9.08 p.p.m. while the one treated with 110 p.p.m. had 41.42 p.p.m. residual chlorine.

The next morning, in order to check the previous work, a new series of tests was projected with the same procedure. This time the break-point was found to be at 106 p.p.m. with a final residual ot 11.49 p.p.m., while the sample treated with 104 p.p.m. showed a residual of 47.66 p.p.m. and 102 p.p.m. gave a residual of 50.7 p.p.m. This series of tests was continued to 152 p.p.m. in order to ascertain whether or nor another "break" might appear. Three 2-liter samples were then set up on the laboratory stirrer and doses of 96, 106 and 116 p.p.m. of chlorine respectively were applied, stirred vigorously, and 20 g.p.g. of lime and 7 g.p.g. of soda ash were added,

stirred slowly for 45 min., filtered, de-chlorinated, and tested. The results for the 96 p.p.m. dose were very poor, giving strong urea and ammonia taste and odor. For the 106 and 116 p.p.m. doses the results were excellent, giving only a very slight woody taste, not at all objectionable. The threshold odor test was not run, but the figure was estimated to be less than 2.

The next problem was how to apply such a tremendous dose of chlorine.

FIG. 1. Arrangement of Chlorine Containers

First, four one-ton chlorine containers were connected to a $\frac{3}{4}$-inch galvanized iron pipe, leading to the ten-tank 150-pound manifold through the ten-tank valves. The plan was to regulate the flow of chlorine by the number of small tank valves that were opened. Within an hour after starting up it was found that four one-ton containers were not enough as they were rapidly freezing up and not enough chlorine was being obtained to reach the break-point.

The plant was stopped and four more one-ton containers were connected. A $\frac{1}{2}$-inch meter connection and 4 ft. of soft drawn copper pipe with iron pipe terminals soldered on made a good connection.

In a relatively short time the plant was started up, but again the tanks began to freeze, the pressure dropped and not enough chlorine could be had.

Four more tanks were rolled in and connected, making a total of 12 containers connected to the $\frac{3}{4}$-inch pipe leading to the improvised control. With this arrangement the tanks did not freeze, but not enough gas to reach the desired quantity of 106 to 116 p.p.m. could be forced through the ten small valves and pipes. The next step was to cut in a $\frac{1}{4}$-inch line with valve from the $\frac{3}{4}$-inch supply header to the 1-inch hose outlet. In this way a sufficient capacity was obtained to make the treatment successful. (See Fig. 1.)


FIG. 2. Treatment Diagram for Super-Chlorination

On February 28, real super-chlorination was initiated with a dosage of about 106 to 112 p.p.m. All the chlorine was applied in a gaseous form, through a rubber hose and a 1-inch silver tube, into the 16-inch suction of the raw water pump. Samples were taken at the chemical house one minute later to check the amount of residual chlorine in the water entering the flash mixer. It was found to range from 9 to 12 p.p.m. At the start with the twelve one-ton containers giving 30 lb. pressure at the control manifold, it required the $\frac{1}{4}$-inch pipe wide open and eight of the ten small valves open to get the right amount of chlorine to reach the break-point. The carbon, which was then running 400 lb. per million gallons, was immediately discontinued. A treatment diagram is shown as Fig. 2.

In making various tests several interesting phenomena were noted. When chlorinated to or beyond the break-point, the raw water,

carrying a light grey turbidity of 30 to 50, within a minute or two turned a decidedly strong tea color, which grew stronger upon standing; and in a short time a floc formed which in about two hours bore a close resemblance to clotted blood, both in color and appearance. It was estimated that 90 per cent of this floc settled and 10 per cent floated. Upon careful de-chlorination with sodium bisulfite and a

TABLE 1
*Sanitary Analysis of Ottumwa Water*

| | FEBRUARY 29, 1940 | | MARCH 6, 1940 | |
|---|---|---|---|---|
| | Raw | Treated | Raw | Treated |
| | *p.p.m.* | *p.p.m.* | *p.p.m.* | *p.p.m.* |
| Ammonia N | 9.40 | 8.25 | 3.60 | 0.96 |
| Albuminoid N | 1.90 | 1.10 | 0.56 | 0.20 |
| Organic N | 3.40 | 1.60 | 3.90 | 1.00 |
| Nitrite N | 0.005 | 0.015 | 0.015 | 0.175 |
| Nitrate N | 0.80 | 0.40 | 0.40 | 0.20 |
| Chloride N(Cl) | 62.00 | 72.00 | — | — |
| Manganese | — | — | 2.00 | 0.00 |

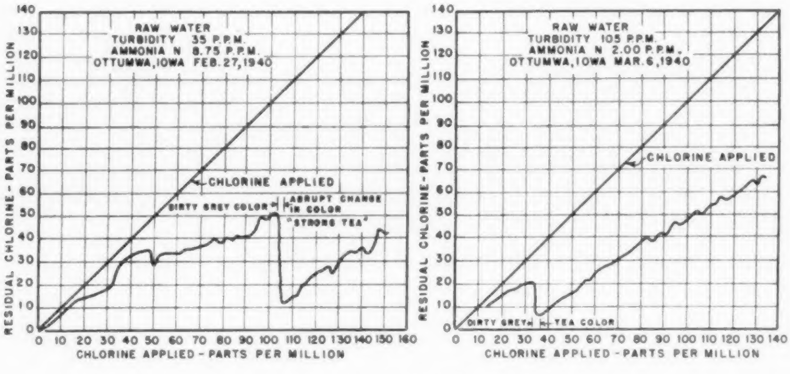


FIG. 3. Results of Analyses During Super-Chlorination

short quick stirring, the red color very quickly disappeared, except for a few of the red particles of floating floc. The settled floc apparently re-dissolved, the water becoming clear, except for a very light pin point floc, gray in color, which quickly started forming. Treating this sample with 16 g.p.g. of lime created a very heavy feathery floc, 100 per cent of which floated. Repeated breaking up with a stirring

rod (8 to 10 times) finally caused about 90 per cent of the floc to settle and remain on the bottom. Upon filtering and warming to 70°F. it had only a very slight woody taste, not at all objectionable.

Another sample of the super-chlorinated water was de-chlorinated before the color change took place, and treated with the same amount of lime. The floc in this case was not nearly as heavy as before and it all settled to the bottom of the jar and stayed there. Upon filtering and warming to 70°F. only the same slight woody taste could be detected, indicating that the final result was not improved by a delay to allow the color to form.

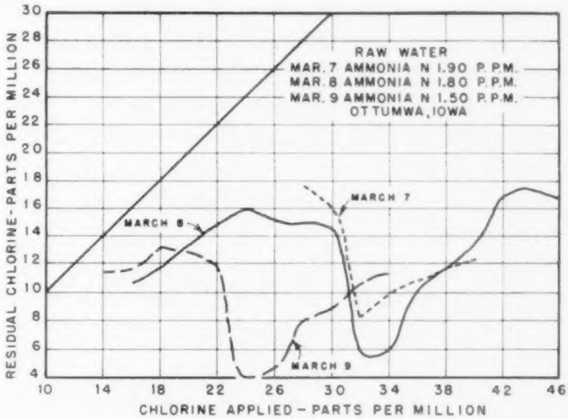


FIG. 4. Results of Analyses After Super-Chlorination Was Discontinued

As an indication of the kind of water being handled, B.O.D. records taken by the State Board of Health engineers directly in front of the intake were obtained. The analysis is as follows:

| *Date* | *B.O.D.* | *Date* | *B.O.D.* |
|---|---|---|---|
| January 12 | 7.3 p.p.m. | January 25 | 28.0 p.p.m. |
| " 22 | 15.0 p.p.m. | " 26 | 28.0 p.p.m. |
| " 23 | 12.0 p.p.m. | February 1 | 41.0 p.p.m. |
| " 24 | 18.0 p.p.m. | " 6 | 45.0 p.p.m. |

No B.O.D. determinations were made after February 6. It is believed, however, that materially higher demands were encountered later in the month—probably as high as 60 to 70.

The bacterial counts were quite low early in January, 160 per ml. on litmus lactose agar, 24 hr. at 37°C. and 1200 per ml. on plain

nutrient agar, 48 hr. at 20°C. The counts reached a high on March 6 of 30,000 per ml. on litmus lactose agar, 24 hr. at 37°C. and 520,000 per ml. on plain nutrient agar, 48 hr. at 20°C., after which date there was a rapid drop back toward normal.

The raw water at the beginning of super-chlorination had a sanitary analysis as shown in Table 1. The samples taken on February 29 and March 6 are the only ones analyzed after super-chlorination started (Figures 3 and 4).

What the local newspapers termed "Super-Colossal Chlorination" was finally discontinued on March 18 as the river was rapidly opening up and substantially more water was flowing.

Some concern was felt over the condition of the raw water pump after handling such volumes of dry chlorine gas. The top half of the pump casing was removed, but examination showed no evidence of damage. The inside of the pump casing as well as all rotating parts had a very thin coating of scale which accumulated during the seven years the pump had been in operation handling a fairly hard raw water. This scale had kept the chlorine from coming in contact with any of the metal.

Our experience, then, seems to indicate that very heavily contaminated water can be successfully handled by super-chlorination.

# Treatment With Copper Sulfate, Chlorine and Ammonia

***By C. K. Calvert***

THE work reported herewith was done on White River water at Indianapolis. Laboratory experiments should precede the application of similar treatment to other supplies.

During the summers of 1937, 1938 and 1939 combinations of copper sulfate, chlorine and ammonia (as the sulfate or anhydrous) have been used to control plankton growth in the large slow-sand filter plant settling basin.

The water enters the basin after already having received its coagulant and pre-chlorination treatment. At the end of the second pass, provision has been made to apply cupri-chlor-ammoniation. The time to this point is about 8 hr. About 36 hr. later the water leaves the basin and flows to the slow-sand filters.

During most of its time in the basin, the water is quite clear and the plankton grow rapidly in the absence of inhibitive treatment.

Following the method of Dr. Harold (1) of the London Metropolitan Water Board, 0.3 p.p.m. each of copper sulfate ($CuSO_4 \cdot 5H_2O$) chlorine and ammonia ($NH_3$) were used. This quantity was insufficient to control growth and a maximum rate of 3.0 p.p.m. was adopted, reductions from that being made as conditions warranted.

Rafter counts and determinations of residual copper sulfate, ammonia and chlorine were made at least daily at points through the basin. So many changing factors affect results that general averages mean nothing. A study of laboratory and operating results, however, leads to various generalizations.

Copper sulfate, chlorine and ammonia are all useful in plankton control, the former being more generally effective. At least one

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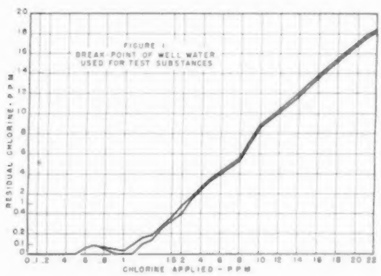
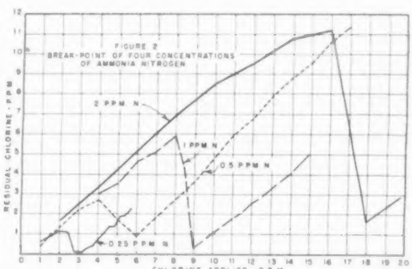
A paper presented on April 23, 1940, at the Kansas City Convention by C. K. Calvert, Superintendent of Purification, Indianapolis Water Co., Indianapolis, Ind.

diatom, *Achnanthes*, resists more than 1 p.p.m. of copper sulfate and is unable to grow in the presence of as little as 0.25 p.p.m. of chlorine. An unidentified filamentous organism withstood 4 p.p.m. of chlorine applied when the water had a demand of about 3 p.p.m. and was eliminated by 2 p.p.m. of copper sulfate.

No virtue has been found in a combination of the three chemicals except when the kinds of organisms present indicate the need for all three. The presence of ammonia, either anhydrous or as the sulfate, seems to have no ability to hold copper sulfate in solution longer than when it is used alone in this water having an alkalinity of about 250 p.p.m. Chlorine seems not to affect the solubility of copper sulfate.

On the basis of daily microscopical examinations, a suitable rate of copper sulfate and chlorine treatment may be applied. No ammonia need be allowed for the formation of cupric-ammonium.




Ammonia may be needed to form chloramine if such an effect is desired. Otherwise ammonia is better left off because it is a bacterial food and may result in the formation of nitrites and odors in distant parts of the system even though slow filters change it to nitrates. The slow filters remove most of the copper sulfate remaining in the settled water.

Sunlight rapidly dissipates even the amines. Large chlorine excess is needed to carry a water through a bright day if aftergrowth is to be prevented. The so-called break-point demand may need to be exceeded.

## Meaning of the Break-Point

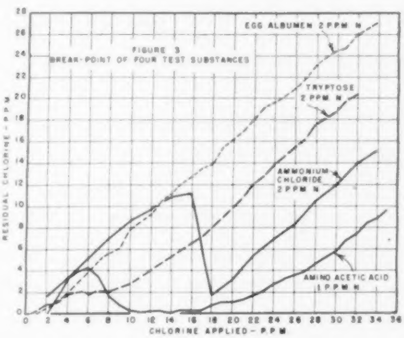
Because a chlorine solution yielding the same amount of chlorine in alkaline and acid titration cannot be made in water containing free ammonia, it was assumed that nitrogen is involved intimately

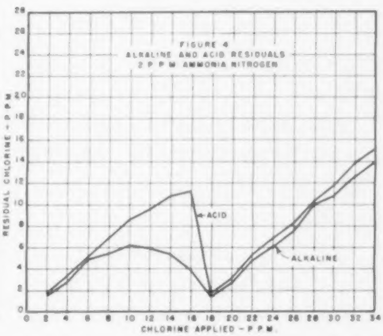
in the phenomenon now called break-point chlorination. This is nothing new. In 1922 Howard (2) used the ammonia content of the raw water to show the need for higher than currently normal chlorine doses and the amount of chlorine required.

### Break-Point and the Shape of the Curve

To study the effect of definite substances on the location of the break-point and the shape of the curve (Fig. 1) a well water with a break-point of 1 p.p.m. was used. Much of the assimilated chlorine was used by mineral substances.

The location of the break-point has been found to be closely in proportion to the free ammonia in water under test (Fig. 2). The results are shown for *N* concentrations doubling from 0.25 p.p.m. to 2.0 p.p.m.




Egg albumin and gelatin (Fig. 3) show no break-point and very low chlorine assimilation.

Tryptose and peptone produce curves with no large initial rise but a rather low residual persists followed by a slow rise beyond what might be expected to be a break-point.

Ammonium chloride forms a spectacular curve. A large initial rise in residual chlorine precedes a sudden drop to a break-point followed by a rapid increase. There is no free ammonia at the break-point.

Amino-acetic acid exhibits the same rapid initial rise in residual but the break-point is followed by a long period of substantially zero residual before the rise begins. This substance does not give color with Nessler's solution but after the addition of chlorine, ammonia

is found in an amount equivalent to the nitrogen in the amino-acetic acid added. There is no free ammonia at the break-point.

Mixtures may be made of these substances which will form the general break-point curves found in the few natural waters so far encountered.

The ratio of nitrogen present as free ammonia in the original sample to the chlorine assimilated at the break-point is 1:7.5. This is substantially the nitrogen-chlorine ratio in nitrogen trichloride, the odor of which is present in samples treated beyond a high break-point even though the pH is above 7. In raw water and in some well water the nitrogen-chlorine ratio varies from 1:7.5 to 1:20 or more, substances other than simple forms of nitrogen having reacted at or just before the break-point is reached.

Neither the alkaline nor acid residual chlorine (Fig. 4) on the left of the break-point will combine quickly with nitrite (Griffin test) while both of them do so on the right of it. The McNamee (3) amine test is positive on the left and negative on the right of the break-point.

Free ammonia-nitrogen results, by direct Nesslerization, are increased when de-chlorination is done with thiosulfate and to a lesser extent, at least, with bisulfite. Ferrous sulfate may remove a little of the ammonia. Nitrates by the reduction method are affected also.

At rates of chlorine application well beyond the break-point, direct Nesslerization of de-chlorinated samples develops true ammonia color in small amount. High chlorine residuals will give a color similar to nitrite when sulfanilic acid is added first and a yellow color when alpha-napthylamine is added first. These analytical interferences complicated a study of the reactions between chlorine and nitrogen.

### Effect of Temperature and Time

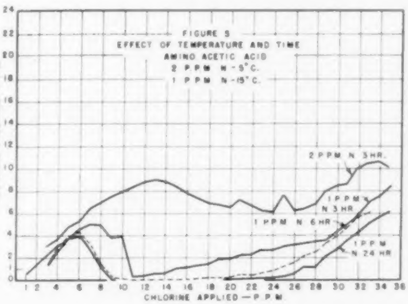
As in any other chemical reaction, temperature is an important item. The low temperature (5°C.) obtaining during test produced the upper line (Fig. 5) showing no definite break-point, while in a subsequent experiment an increase of 10°C. resulted in a positive break-point and the long valley even with a 3-hour contact. Especially in dilute solutions is time an important factor in the completion of reaction. The lower lines represent titrations of portions of the same samples at 3, 6 and 24 hr. The 3-hour contact time gave no suggestion that the reaction was incomplete. The 6-hour

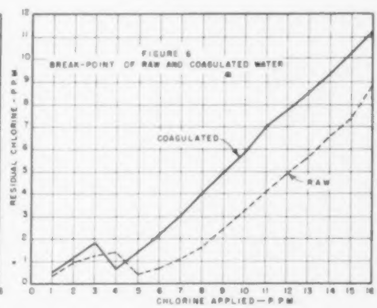
time not only extended the low chlorine zone but gave indication of a further change to come which was found at the end of 24 hr. and which extended the low chlorine zone still further. Even at the end of 24 hr. there is a slight break in the line, rising beyond the low zone which may indicate a further extension of reaction.

Comparative work on substances should be done at a constant temperature. To translate laboratory results into plant practice the work must be done at the temperature of the natural water with a contact time equal to that provided in the plant.

## Effect of Coagulation

The laboratory coagulation of raw water (Fig. 6) with a turbidity of 260 p.p.m. using 500 lb. per mil. gal. of alum, reduced the total organic nitrogen from 1.76 p.p.m. to 0.81 p.p.m. but with no change



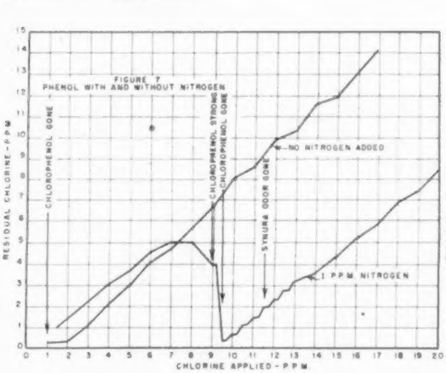

in the free ammonia which was 0.35 p.p.m. Coagulation lowered the break-point only 1 p.p.m. but the shape of the rising curve beyond the break-point of the uncoagulated water is much flatter, showing that coagulable matter is consuming chlorine even beyond the break-point.

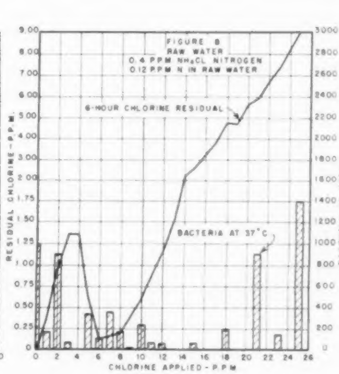
Chlorination after coagulation saves some chlorine but in most plants the time remaining after sedimentation is too short to permit completion of the reaction, especially at low temperatures. Chlorination of raw water suppressed completely the odor of deposited sludge in the settling basin this winter, and reduced it decidedly last summer. Decomposition of sludge adds odor to water passing over it.

As long as the pH is not affected seriously, high chlorine rates do not interfere with coagulation and may be a slight help.

## Taste and Odor

A number of odors associated with sewage pollution are destroyed at the break-point even though they may be accentuated with lower chlorine rates. There may be a "musty" or "river" odor remaining which reasonable amounts of carbon will remove. It may be applied after the chlorine effect is completed and, in some cases, with the chlorine. When ammonia is absent or very low, chlorophenol is formed and then destroyed with what now seem to be small doses of chlorine (Fig. 7). The odor produced by both 10 and 50 parts per billion of phenol disappears with the use of 1 p.p.m. of active chlorine (4). When ammonia is present, chlorophenol odor is present just before the break-point and absent when the break-point is reached.



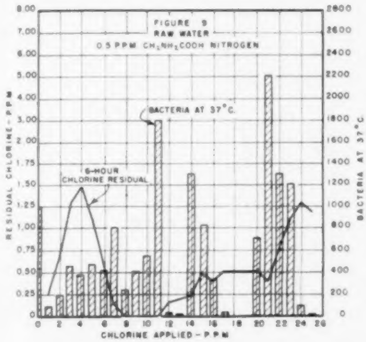

The odor produced by *Synura* is destroyed only after passing the break-point, the amount of excess chlorine required being governed by the intensity of the odor. With a break-point of 3.0 p.p.m. a chlorine rate of 5 p.p.m. was required. It is believed most tastes are not destroyed until the ammonia-chlorine reaction is completed.

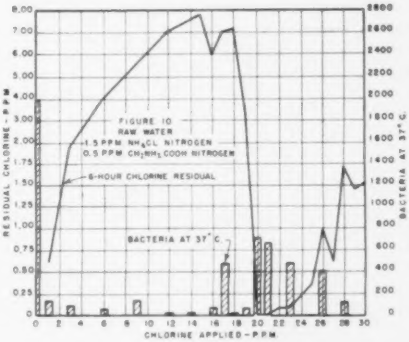
## Bacterial Kill

Even in raw water with 3.0 p.p.m. of free ammonia nitrogen, 1 p.p.m. of applied chlorine usually will kill coliform organisms within 3 hr. Most of the bacteria are killed with the application of rather small chlorine doses but the final reduction comes beyond the break-point regardless of its location. (See Figs. 8, 9 and 10.) Very high counts appear in portions well beyond the break-point in every series examined. There must be a reason for them and it is being

sought. Only spore-forming bacteria have been recovered from samples just before and beyond the break-point. It is not surprising that some of them are gas formers. Figure 11 shows the effect of high chlorine dosages on the settled water. It will be noted that well before the break-point is reached, the bacteria at 37°C. have been reduced to a very low figure and that there are no high bacterial counts above the break-point corresponding to those which appear in similar experiments on the raw water. This may be simply another demonstration of the oft-recurring evidence that the chlorination of turbid waters, that is, waters containing gross solid particles, is not always likely to be effective.

In well coagulated water small chlorine doses result in almost complete bacterial kill and spore-forming gas formers are generally ab-




sent in 100 ml. portions. In raw water the bacteria probably are protected within suspended solids. It may be that chlorine is able to break up clumps of bacteria and in this way cause apparent increase in counts.

## Break-Point and Water Quality

The weather during the first 3 months of 1936 and 1940, was similar. In the earlier year pre-chlorination was at about 5 lb. per mil. gal. and in the present year it ranged from 35 lb. to a maximum of 175 lb. per mil. gal.

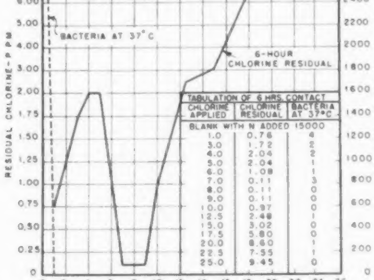
In 1936 about 90 per cent of the 10 ml. portions of settled water contained gas formers and 4 per cent confirmed. In 1940 less than 30 per cent contained gas formers and 0.3 per cent confirmed. The plant effluent contained no coliform organisms in 100 ml. in either year. The color of finished water in 1936 was 10 p.p.m. and in 1940,

4 p.p.m., the color produced by high chlorine rates being removed easily in coagulation and filtration.

The lower rate of chlorine treatment was sufficient to reduce the significant organisms to a point much below that required even for finished water. The reduction in color is unimportant since 10 p.p.m. is not objectionable. Methods of recording taste are inexact and comparison is difficult but it is believed that the finished water in 1940 was superior to that in 1936 with respect to taste and odor. The cost of the carbon used in 1936 was about the same as the chlorine cost in 1940.

## Method of Break-Point Control

The most simple means of break-point control for many waters is the Laux method (5) which takes advantage of the difference in




| CHLORINE APPLIED | CHLORINE RESIDUAL | BACTERIA AT 37°C |
|---|---|---|
| BLANK WITH N ADDED | | 15000 |
| 1.0 | 0.76 | 4 |
| 3.0 | 1.72 | 2 |
| 4.0 | 2.04 | 2 |
| 5.0 | 2.04 | 1 |
| 6.0 | 1.08 | 1 |
| 7.0 | 0.11 | 3 |
| 8.0 | 0.11 | 0 |
| 9.0 | 0.11 | 0 |
| 10.0 | 0.97 | 0 |
| 12.5 | 2.48 | 1 |
| 15.0 | 3.02 | 0 |
| 17.5 | 5.80 | 0 |
| 20.0 | 8.60 | 1 |
| 22.5 | 7.55 | 1 |
| 25.0 | 9.45 | 0 |

speed of color development by ortho-tolidine with active and partially bound chlorine. At the left of the break-point (Fig. 4), color development is slow while at and to the right of it, the color comes quickly and reaches its maximum almost at once.

The unreliability of ortho-tolidine for the control of residual chlorine in finished water resulted in the substitution of the iodimetric method more than a year ago. While it is more cumbersome it is more accurate and it may be used to show active and inactive chlorine and, consequently, the position of the break-point.

A sample falling to the left of the break-point, titrated without the addition of acid, shows a much lower chlorine content than when

acid is present. The upper line (Fig. 4) is the chlorine found by acid titration and the lower shows that found with no acid present. At and beyond the break-point the two titrations are nearly alike. In plant control the titration of samples of treated water will show the relationship that the rate of chlorine application bears to the break-point. In case of doubt, the sample may be heated to 43°C. for ten minutes before the additions of reagents. If no residual chlorine remains, it is very near the break-point. If acidification releases no additional chlorine after the alkaline titration, the break-point is passed. If no chlorine is released without acid but is released with acid, the break-point has not been reached.

Alkaline and acid titration figures are helpful in studying the cause of the phenomenon but it is probable that plotting time for maximum ortho-tolidine color development against chlorine applied would produce curves of much the same shape.

*Standard Methods* prescribes the titration of residual chlorine without the addition of acid but with a long contact time with potassium iodide and Koschkin (6) has called attention to the greater sterilizing action of the chlorine titratable without the use of acid.

The phenomena exhibited by chlorine in water are not only interesting but have practical application in the purification problems in most water treatment plants. A full understanding of causes and effects will clarify the present confusing situation.

The author wishes to acknowledge with appreciation the assistance given by: Neil Kershaw, Chief Chemist, E. R. Hupp, Junior Chemist; M. P. Crabill, Plant Engineer—all of the Indianapolis Water Co.;—and D. E. Bloodgood, Supt. of the Indianapolis Sanitation Plant.

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* These references came to the attention of the author after the preparation of the paper. They deserve the attention of any one interested in chlorination.

# Control of Algae at Appleton, Wisconsin

*By William U. Gallaher*

THE year 1939 will be remembered among water works men in the Middle West either as a year with extraordinary algae troubles, or as the beginning of what may prove to be a perennial siege of extremely abundant algae growths. It is hoped that it was merely an unusual year.

Difficulties experienced with algae at Appleton, Wisconsin, in 1939 were not greatly different in character from those encountered with microscopic organisms in other places and at other times. Discussion of them is warranted only because they were unusually severe. This does not purport to be a profound research paper on algae troubles and their cures. In times of great stress one cannot take the time to lay out and follow through accurate and complex investigations and experiments; routine must be increased to take care of critical conditions and there is little time for anything but the things requiring immediate attention.

The source of the Appleton water supply is the Lower Fox River that carries the overflow from Lake Winnebago to Green Bay. The river water at Appleton, six miles down the river from Lake Winnebago, is practically the same as the water in the lake except that domestic sewage and trade wastes, from a population of about 242,000, are contributed to the river at Neenah and Menasha after primary treatment. The cities of Oshkosh, Neenah, and Menasha and numerous paper mills also use Lake Winnebago as their source of supply (see Fig. 1).

Lake Winnebago is oval-shaped in outline with a maximum length of 30 mi. and a maximum width of about 10 mi. Its average depth is 15.5 ft. with a maximum depth of 21 ft. The capacity of the lake

A paper presented on April 23, 1940, at the Kansas City Convention by William U. Gallaher, Chemist and Superintendent, Appleton Water Plant, Appleton, Wis.

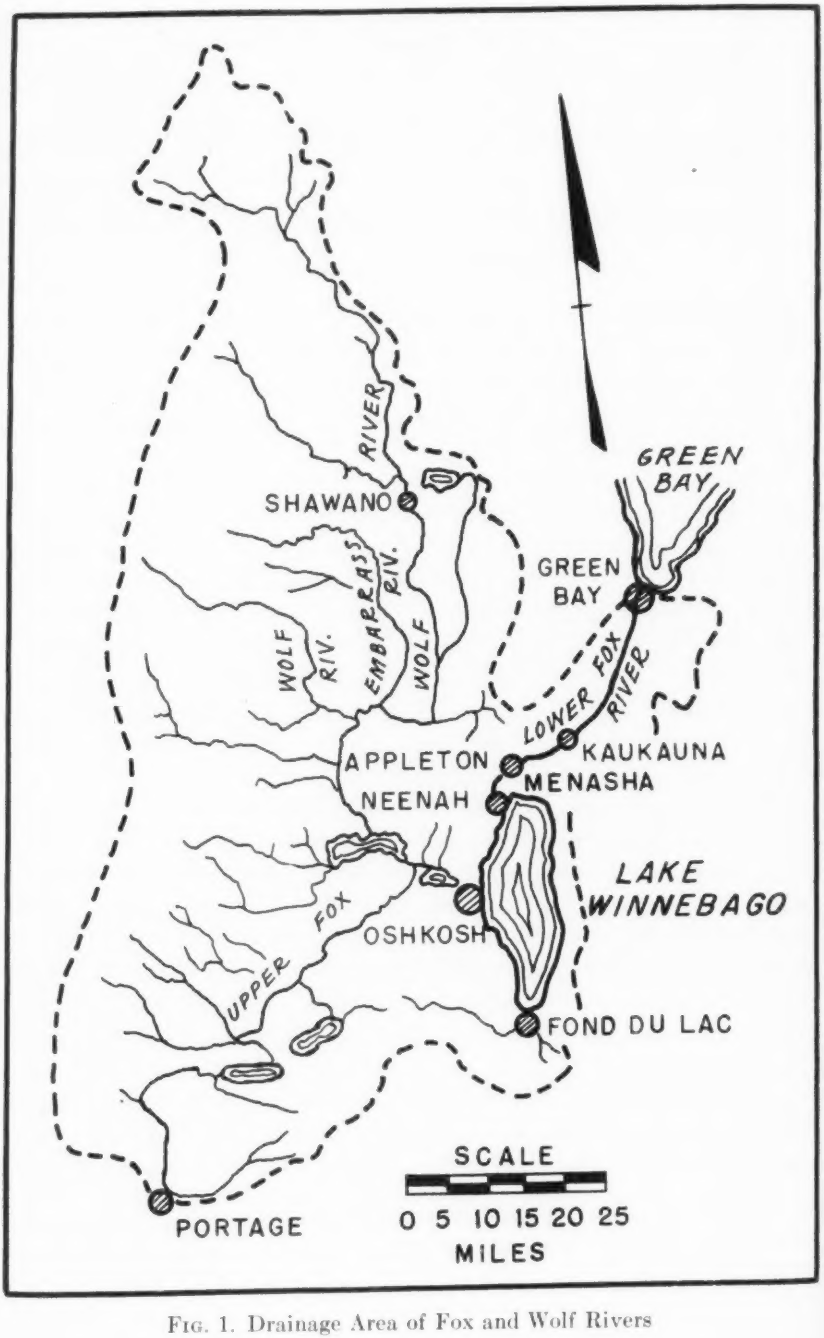


FIG. 1. Drainage Area of Fox and Wolf Rivers

is 785 billion gallons and the average discharge of water down the Fox River is $2\frac{3}{4}$ billion gallons daily. This means an average theoretical detention period in the lake of 286 days or nine months. The period of detention in the lake varies, however, between wide limits, depending on evaporation, short circuiting, seasonal variation in flow, and control of the discharge for power and navigation purposes.

The shallow lake, with its large surface area, agitated at frequent intervals by wind action, has always been a fertile medium for the growth of plankton with a maximum growth in July and August. Control of algae in the water from this lake by the use of copper sulfate has never been given any serious consideration because of the enormous cost such treatment would involve.

## Algae Concentrations in the River Water

The growth of plankton in Lake Winnebago was much more prolific in 1939 than in any previous year. During the summer there were few cloudy days and little rainfall; but other years with much sunshine and drought conditions did not produce such a luxuriant growth of algae. The best explanation seems to be that unusually abundant algae growth depends primarily on an extraordinary increase in ultra-violet radiation.

As early as June we had some indication that algae growth was active in the water supply at Appleton. The lake and the river were noticeably green, *Aphanizomenon* being the predominating type. In July *Anabaena* became the predominating type with a concentration of 9,000 cubic standard units (c.s.u.) per ml. In August, *Anabaena* were still present but *Coelospharium* (2,500 c.s.u. per ml.) together with some *Clathrocystis* had the upper hand. By September, the diatom *Microspira* (6,000 c.s.u. per ml.) became most common. A total routine plankton count was not made but it exceeded 10,000 c.s.u. per ml. during most of the summer period.

The high concentration of algae was the indirect cause of the destruction of thousands of fish near the head of the Lower Fox River. Previous to this incident there had been a period of prevailing southerly winds that carried floating algae to the north end of the lake. Then the wind changed to an easterly direction, blowing the accumulated scum to the head of the river at a time when the discharge from the lake into the river was greatly reduced. The concentration of algae became so great at this point that decomposition took place and the oxygen in the water was depleted to the point that fish life could not survive. From August 17 to 19, fish of

all kinds, including such game fish as pike, sturgeon, perch, etc., as well as rough fish such as carp, sheepsheads, and bullheads, died in large numbers. Most remarkable was the fact that even the crayfish were unable to endure the condition of the water and thousands of them crawled to the edge of the river covering the shore to a depth of several inches.

This incident attracted wide attention and the local press carried, of course, accounts and pictures of the dead fish. This, as might have been expected, had the unfortunate psychological effect of attracting the attention of consumers to the possibility of trouble with the water. On the other hand it had the good effect of portraying vividly to the general public the condition of the lake and the river water, thus making the consumers more sympathetic.

Disturbed conditions such as these were made even more critical by the high coliform index of the river water. The average Phelps Indices per 100 ml. of the river water for the summer months in 1939 were as follows: June, 9,920; July, 21,640; August, 8,140; and September, 15,586. These high coliform indices were present in spite of the high pH (8.5 to 9.0) of the river water. According to H. W. Streeter (Public Health Reports, **48:** 15) the pollution load on the plant reached the concentration limits that could be safely handled by a filter plant using double chlorination.

Bad raw water conditions such as those mentioned above bring out the strong and the weak points of plant units. For this reason the performance of such plant units as aeration, sedimentation, chlorination, and filtration during the period will be discussed briefly and special points not covered in such units will be considered.

## Aeration

The use of aeration as a means of removing odors from water was one of the earliest methods of artificial water purification. Many of the present plants have aerators as a step in water treatment, while others do not use them, chiefly because they involve added pumping costs. The Appleton water plant has an aerator of the spray type which is used except during the winter season. It consists of four sections each equipped with 18 "Spraco" nozzles. Any one or all of the sections may be used at one time to obtain a spray height of about eight feet. Alum is applied to the water as it goes to the aerators.

Table 1 and Figure 2 show the effect of aeration during four sum-

mer and fall months of 1939. These results indicate that during warm water conditions aeration accomplished an appreciable odor removal of from 40 to 50 per cent. As the water cools, the odor of

TABLE 1

*Odor Removal by Aeration—1939*

| MONTH | TEMP. | NUMBER OF SAMPLES | AVERAGE T.O. | | PER CENT REDUCTION T.O. | | |
|---|---|---|---|---|---|---|---|
| | | | Raw | Aerated | Ave. | Max. | Min. |
| | °F. | | | | | | |
| August | 73.3 | 27 | 65.5 | 41.0 | 37 | 68 | 10 |
| September | 68.0 | 26 | 45.0 | 22.0 | 51 | 69 | 38 |
| October | 52.4 | 25 | 15.7 | 10.8 | 31 | 50 | 20 |
| November | 39.0 | 30 | 13.2 | 10.0 | 24 | 38 | 20 |

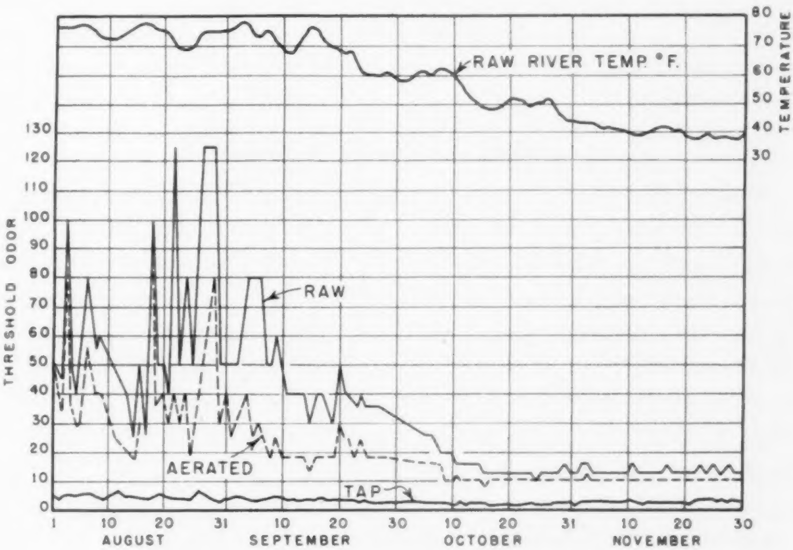


FIG. 2. Effect of Aeration on Lake Winnebago Water

the raw water lessens with a corresponding reduction in the efficiency of the aerator to about 25 per cent.

A conservative estimate of the carbon required to remove one unit of threshold odor is 1 p.p.m. Actual experience indicates that the amount of carbon required at Appleton is much greater than this. In September the average reduction in threshold odor was 23.

This meant a saving of at least 23 p.p.m. of carbon which at a cost of \$0.40 per part would amount to a saving of \$10.20 per mil. gal. of water. The cost of low lift pumping at Appleton is about \$1.50 per million gallons. Much of this pumping would be required to send the water through the plant even if there were no aeration. Thus it appears that in the summer months aeration pays big dividends since the figures indicate that aeration saves about \$9.00 per million gallons in the cost of carbon. When the water is colder and the average reduction is below 4 p.p.m. in the threshold odor, aeration does not appear to be profitable.

It should be pointed out, however, that the odorous compounds vary greatly in volatility and that the above reasoning may not apply under all conditions. Moreover, the character of odors has a great deal to do with their allowable residual concentration. There is now a means of measuring concentration by the threshold method. It is extremely desirable from an economic standpoint to devise some means of determining the odor character in relation to concentration.

## Settling and Pre-Chlorination

It is common knowledge that algae are not readily removed by alum coagulation, and this proved to be the case at Appleton. Clay and other inert materials have been used to drag down the organisms but there are at present no facilities in the Appleton plant for adding clay. One Appleton paper mill tried clay during the summer of 1939 and reported that its use gave no beneficial results. Since color must be removed, lime cannot be used below softening doses. For the most part good results were obtained by the use of rather high doses of alum (up to 7 grains) which gave a final pH of 6.6 to 6.8.

Additional and severe trouble was experienced from the decomposition of the sludge at the bottom of the settling basins; this resulted in large increases in bacterial counts. Samples were taken at different depths in the largest basin and it was found that the water in the upper portion of the basin was almost sterile, while the sludge at the bottom of the water contained from 17,000 to 300,000 bacteria per ml.

The residual chlorine of the water leaving the settling basin was maintained at 1 p.p.m. through the warmest water conditions in order to obtain a water of satisfactory bacterial quality. Chlorine

was applied up to 6 p.p.m. and ammonia as ammonia sulfate, in a ratio to chlorine of 1 to 6.

Another complication was the scum of algae and alum which formed on the water in the settling basin. This scum decomposed giving rise to extremely foul, sour odors. Since water is removed from the surface of the basin the scum was probably a contributing cause of high odors in the settling basin effluents. Basins were cleaned as frequently as every third week during the worst water conditions. The effect of settling on odors is shown in Table 2.

At first glance no benefits seem to have been derived from the addition of activated carbon to the basin influent. During the month of September when carbon was applied at an average dosage of 30 p.p.m. and the average odor of the aerated water was 22 there

TABLE 2

*Effect of Aeration*

| MONTH, 1939 | ACTIVATED CARBON | AVE. T.O. | | CHLORINE | | $NH_3$ |
|---|---|---|---|---|---|---|
| | | Aerated | Settled | Applied | Settled residual | |
| | *ave. p.p.m.* | | | *p.p.m.* | *p.p.m.* | *p.p.m.* |
| August | 26.3 | 41.0 | 31.0 | 4.07 | 1.1 | 0.72 |
| September | 30.1 | 22.0 | 22.5 | 3.4 | 0.83 | 0.6 |
| October | 17.5 | 10.8 | 9.4 | 2.2 | 0.54 | .42 |
| November | 8.5 | 10.0 | 8.0 | 1.3 | 0.3 | .32 |

was no drop in the threshold odor between the inlet and the outlet of the settling basin.

Many factors, however, tended to counteract the beneficial effect of the carbon. Laboratory experiments indicated that the addition of chlorine in the quantities then being used in the plant increased the odor about 50 per cent. Decomposition of the sludge and scum also contributed to an increase in odor. The odor of the water leaving the basin would probably have been much greater had carbon not been used.

It appears that the proper method of handling water containing high organic matter either living or decomposing is to remove as much of the objectionable material as possible by primary treatment before adding activated carbon. The primary basins should be equipped to take the unstable sludge away from the basin as soon as possible. Carbon should be added as a secondary treatment, with

sufficient mix provided to effect good contact between the carbon and water. In this way, the sludge formed in the primary tanks will not be given an opportunity to recontaminate the water passing through the basin and the most effective use of carbon will be obtained.

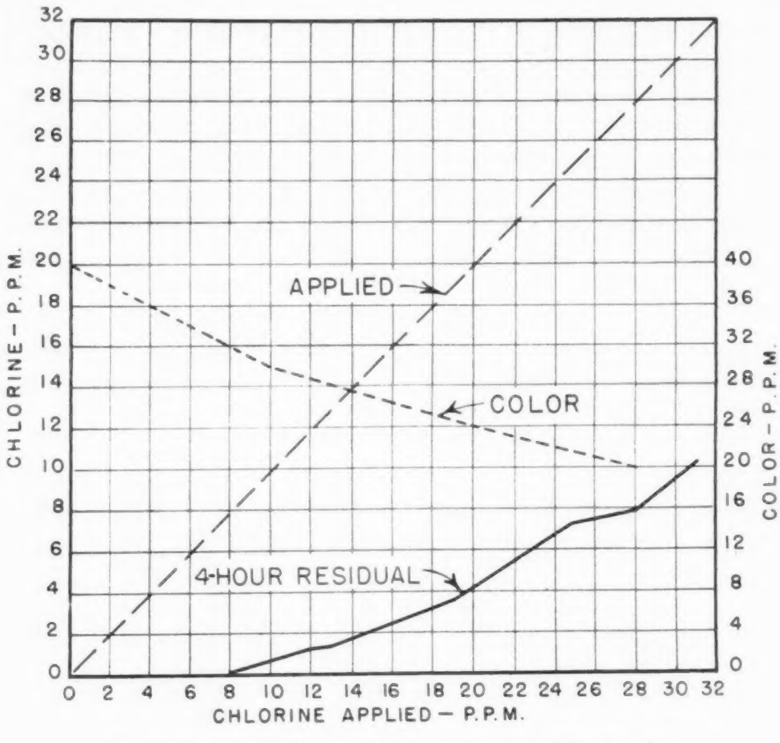


FIG. 3. Residual Odor and Color After De-Chlorination

## Super-Chlorination

It has been suggested that super-chlorination might destroy the tastes and odors in the water. A series of jars containing raw water was set up and chlorine water was added to each jar, starting with low dosages and increasing to 31 p.p.m. After addition of chlorine, the samples were stirred for 10 min., allowed to stand 4 hr., and the residual chlorine determined. The odor and color remaining in a few of the samples after de-chlorination were also determined. (See Fig. 3 and Table 3).

The 4-hour chlorine demand appeared to be between 8 and 9 p.p.m. Starting at about this application, residuals mounted until at 31 parts of chlorine applied, the residual was 10 p.p.m. No definite break-point was noted although the chlorine residual line did not parallel the applied chlorine line even at the high dosages. The odor was reduced about 55 per cent leaving an appreciable odor at fairly high chlorine application. With increasing amounts of chlorine there was a reduction of color amounting to 50 per cent at high dosages. The bodies of the organisms no doubt destroyed some of the effects of chlorination.

## Filters

That the filters caused considerable trouble goes without saying. Runs were greatly shortened and the sand became so filled with algae that any negative head had a tendency to cause surface shrinkage. Because there was no surface wash, filters were drained to the sand and hosed with a $1\frac{1}{4}$-inch jet of water. On the whole, only fair results were obtained since the algae up to 100 c.s.u. per ml. passed the filters. Surface wash has since been installed.

TABLE 3

*Effect of Chlorination*

| | RAW | CHLORINE APPLIED—P.P.M. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 10 | 12 | 13 | 16 | 19 | 22 | 25 | 28 | 31 |
| Residual Chlorine—4 hr.—p.p.m. | 0 | 0.1 | 0.65 | 1.2 | 1.2 | 2.4 | 3.5 | 5.4 | 7.3 | 7.9 | 10.3 |
| Odor—T. O. Units | 40 | 30 | 20 | 17 | | | 18 | | | | |
| Color—p.p.m. | 40 | | 30 | | | | 25 | | | 20 | |

In spite of the fact that almost sterile water was applied to the filters, the effluent contained a large number of bacteria, many of which were of the coli-aerogenes group. This was due to decomposition of micro-organisms and other organic matter in the filters. Sterilization by injecting chlorine into the lateral system of the filters was used. This had some beneficial effects for from one to three days but after that high bacteria counts returned. Application of copper sulfate to one filter resulted in the discharge of extremely foul smelling filter effluent. This was cleared up by repeated washings and the application of chlorine, but the experiment showed that

copper sulfate was impractical for this purpose. The only recourse was frequent filter washing and maintenance of a high residual in the finished water.

New sand, it was found, did not remove the taste and odors as well as the old coated sand. One of the eight filters had been completely reconditioned during the winter of 1938–1939. During the entire summer of 1939 this filter caused much trouble from taste and odors and most of the time it could not be used. An adjoining city reported the same experience with a filter that was equipped with surface wash. It may be possible to condition this filter in time but for the present it is quite a nuisance since it is out of balance with the rest. The effective size of the sand in all the filters was between 0.45 and 0.50 mm. Finer sand might prevent the passage of carbon and fine silt but on the other hand it might cause serious filter run shortages.

Much of the odor was removed by the filters on which carbon was continuously applied in amounts as high as 10 p.p.m. During the summer the filters removed this carbon without material shortening in filter runs. However as the water cooled off it was found that carbon passed the filters even at small applications and its use had to be restricted to the raw water.

## Lime Treatment

Softening the water had been under consideration at Appleton before the summer of 1939 and, before conditions became too severe, some investigations were made to determine the effectiveness of algae removal by lime softening. Counts from the Neenah lime softening plant indicated that softening reduced the algae count from 3,850 to 39 c.s.u. per ml.—a removal of about 99 per cent. Jar tests also indicated that most of the algae were removed by lime treatment and settling.

The lime treatment also has an appreciable effect in lessening the chlorine demand. The 25-minute chlorine demand of the untreated raw water was about 5.34 p.p.m. of the aerated filtered water, 4.31 p.p.m. of the lime treated and filtered water, both at high pH and when neutralized to pH 7.0, was 2.76 p.p.m. Therefore lime treatment appears to reduce the chlorine demand about 50 per cent.

### Distribution System Troubles

The water leaving the treatment plant before final chlorination had a threshold odor below 5 and most of the time was 3 or less. At the Appleton plant there is a small clear-well capacity and it would be difficult to add chlorine to the filter effluent, since each filter discharges directly into the clear well. As there were many bacteria in the filter effluent, rather large residuals had to be maintained in order to have a satisfactory bacterial count in the tap water. At times a residual of 0.35 to 0.40 p.p.m. as determined by starch iodide or from 0.50 to 0.60 as determined by ortho-tolidine was maintained in the tap. Tests indicated that this chlorine was chiefly combined as chloramines.

The water did not have a particularly undesirable or unpleasant taste at the plant but at the time this high residual was carried, iodoform tastes were frequently reported at different points in the distribution system. Possibly some oxidation of organic matter in the water itself or decomposition of already deposited algae caused this after-taste.

Moldy or mildewy tastes appeared in the distribution system during September, at times when such tastes were not present at the plant. This taste was thought to have been due to the decomposition of algae that had accumulated in certain mains during the critical period. The evils of algae, like "the evils that men do," seem to live after them.

# Super-Chlorination With Ferrous Sulfate De-Chlorination

***By Walter Strockbine***

THE Maiden Creek Filter Plant at Reading, Pa., receives its water from the impounded Maiden Creek. This creek is not contaminated by any trade waste of an objectionable nature, the odors in the raw water being due to micro-organisms and decaying organic matter.

Since the rapid sand plant has been in operation, difficulty has been experienced in obtaining good coagulation when the water contained much organic matter. This was experienced when either alum or iron salts were used as the coagulant.

Many things, claimed to aid coagulation, have been tried in this water. Pre-chlorination was most successful. A dosage of 10 lb. per million gallons has been used for this purpose but nearly always has created or intensified odors.

Since pre-chlorination was successful and since there was no other oxidizing agent available at a cost nearly as low as chlorine, much thought was given to the possible solution of the odor difficulties encountered with pre-chlorination. Mr. Howard, of Toronto, has made many reports of the satisfactory performance of super-chlorination for a number of years, but the possibility of super-chlorinating Reading water was not seriously considered because of the necessity of de-chlorination. Control apparatus would have had to be purchased to feed either sodium thiosulfate or sulfur dioxide for the process. The method would also have required the handling and proportioning of another chemical. While beds of granular activated carbon could have been used for the purpose without much attention, it would have been costly to build them into the plant.

In June, 1939, it was decided to try ferrous sulfate as a de-chlorinating agent. At that time ferrous sulfate was already being used

A paper presented on April 23, 1940, at the Kansas City Convention by Walter Strockbine, Chief Chemist, Bureau of Water, Reading, Pa.

in the plant for coagulation in the lime softening treatment. Since the decision was made a large number of laboratory tests have been run, using ferrous sulfate as the de-chlorinating agent, to determine the effect of super-chlorination on the Maiden Creek water. In an

TABLE 1

*Ferrous Sulfate as a De-Chlorinating Agent, June 30, 1939*

| $Cl_2$ APPLIED TO RAW WATER | | $Cl_2$ RESIDUAL AFTER 2-HOUR REACTING PERIOD | $Cl_2$ CONSUMED IN 2 HR. | 200 LB./MIL. GAL. FERROUS SULFATE ADDED PLUS LIME. RESIDUAL $Cl_2$ AFTER 2 HR. SETTLING | ODOR | |
|---|---|---|---|---|---|---|
| | | | | | Hot | Cold |
| *lb./mil. gal.* | *p.p.m.* | *p.p.m.* | *p.p.m.* | *p.p.m.* | | |
| 5 | .60 | .28 | .32 | .09 | Slight musty | 0 |
| 10 | 1.20 | .35 | .85 | .09 | Slight musty | 0 |
| 20 | 2.40 | .20 | 2.20 | .04 | 0 | 0 |
| 30 | 3.60 | .65 | 2.95 | .05 | Slight musty | 0 |
| 40 | 4.80 | 1.20 | 3.60 | .05 | Slight musty | 0 |
| 50 | 6.00 | 2.00 | 4.00 | .10 | Slight musty | 0 |

TABLE 2

*Ferrous Sulfate as a De-Chlorinating Agent, July 3, 1939*

| $Cl_2$ APPLIED TO RAW WATER | | $Cl_2$ RESIDUAL AFTER 2-HOUR REACTING PERIOD | $Cl_2$ CONSUMED IN 2 HR. | 200 LB./MIL. GAL. FERROUS SULFATE ADDED PLUS LIME. RESIDUAL $Cl_2$ AFTER 2 HR. SETTLING | ODOR* | |
|---|---|---|---|---|---|---|
| | | | | | Hot | Cold |
| *lb./mil. gal.* | *p.p.m.* | *p.p.m.* | *p.p.m.* | *p.p.m.* | | |
| 5 | .60 | .17 | 143 | .07 | 0 | 0 |
| 10 | 1.20 | .34 | .86 | .04 | 0 | 0 |
| 15 | 1.80 | 1.02 | .78 | .03 | 0 | 0 |
| 20 | 2.40 | .68 | 1.72 | .03 | 0 | 0 |
| 25 | 3.00 | .34 | 2.66 | .03 | 0 | 0 |
| 30 | 3.60 | 1.36 | 2.24 | .03 | 0 | 0 |

* Plant effluent at the time had pronounced musty odor; 10 lb./mil. gal. was being used to aid coagulation but only approximately 4 min. contact period was available before ferrous sulfate was applied.

experiment on June 30, 1939, it was found that 200 lb. per mil. gal. of ferrous sulfate would de-chlorinate what was left of 50 lb. per mil. gal. of chlorine, after a 2 hr. reaction period. The result of the first test is shown in Table 1.

In Table 2, it will be seen that there was a dip in the residual

chlorine after a 2 hr. reacting period with the 25 lb. per mil. gal. dose. Similar low points have been observed in most of the tests run. They have occurred at different dosages due to changing characteristics of the water. A large number of tests failed to show this, however, in the increments used. The chlorine residual after the

TABLE 3

*Ferrous Sulfate as a De-Chlorinating Agent, August 14, 1939*

| $Cl_2$ APPLIED TO RAW WATER | | 200 LB./MIL. GAL. FERROUS SULFATE ADDED PLUS LIME. $Cl_2$ RESIDUAL AFTER 1-HOUR SETTLING | $Cl_2$ CONSUMED IN 1 HR. | 200 LB./MIL. GAL. FERROUS SULFATE ADDED PLUS LIME. SETTLED 1½ HR. $Cl_2$ RESIDUAL |
|---|---|---|---|---|
| *lb./mil. gal.* | *p.p.m.* | *p.p.m.* | *p.p.m.* | *p.p.m.* |
| 10 | 1.20 | .80 | .40 | .10 |
| 20 | 2.40 | .16 | 2.24 | .00 |
| 30 | 3.60 | .48 | 3.12 | .00 |
| 40 | 4.80 | 1.73 | 3.07 | .06 |
| 50 | 6.00 | 2.67 | 3.33 | .10 |
| 60 | 7.20 | 3.60 | 3.60 | .10 |

TABLE 4

*Ferrous Sulfate as a De-Chlorinating Agent, August 18, 1939**

| $Cl_2$ APPLIED TO RAW WATER | | $Cl_2$ RESIDUAL AFTER 2-HOUR REACTING PERIOD | $Cl_2$ CONSUMED IN 2 HR. | 200 LB./MIL. GAL. FERROUS SULFATE ADDED PLUS LIME. SETTLED 2 HR. ODOR OF SETTLED WATER | | TURBIDITY OF SETTLED WATER |
|---|---|---|---|---|---|---|
| | | | | Hot | Cold | |
| *lb./mil. gal.* | *p.p.m.* | *p.p.m.* | *p.p.m.* | | | |
| 0 | 0 | — | — | 3 V | 2 V | 4.5 |
| 10 | 1.20 | .00 | 1.20 | 3 V | 2 V | 3.0 |
| 20 | 2.40 | .63 | 1.77 | 2 V | 1 V | 2.5 |
| 30 | 3.60 | .63 | 2.97 | 1 g | 0 | 2.5 |
| 40 | 4.80 | 1.50 | 3.22 | 0 | 0 | 2.3 |
| 50 | 6.00 | 2.52 | 3.18 | 2 M | 1 M | 2.0 |
| 60 | 7.20 | 3.46 | 3.74 | 2 M | 1 M | 1.6 |

* Few *Anabaena* present.

application of ferrous sulfate was determined by the ortho-tolidine method and may have been high due to some iron passing the glass wool filter which was used to filter the water before the test was run.

Table 3 shows that a dip in the residual chlorine occurred at the 20 lb. per mil. gal. dose. In the test, amounts of chlorine up to 60 lb. per mil. gal. were used.

The effect of super-chlorination on odor is shown in Table 4.

Intensity of odor is expressed by a number as in *Standard Methods* prior to 1936. The value of the "Spaulding Threshold Odor Test" is appreciated, but there was no time to apply it. Since the T. O. test is based on a series of dilutions, the hot zero odor as reported would be the same, because no dilutions would be required. The water was brought to approximately 65 to 70°C. before observing the hot odor in these tests. In several, the odor was reduced from an intensity of 5 to 0 as measured by the old method. Since an intensity of 5 according to this method is very strong, or "An odor of such intensity that the water would be absolutely unfit to drink," it must be realized that super-chlorination was very successful in eliminating odors existing in the water.

TABLE 5

*Odor Caused By Anabaena Destroyed By Super-Chlorination, August 28, 1939*

| $Cl_2$ APPLIED | ODOR OF SETTLED WATER | | TURBIDITY OF SETTLED WATER |
|---|---|---|---|
| | Hot | Cold | |
| *lb./mil. gal.* | | | |
| 0 | 4 d | 3 d | 3.5 |
| 10 | 3 d | 2 d | 3.0 |
| 20 | 3 d | 2 d | 2.8 |
| 30 | 2 d | 1 d | 2.5 |
| 40 | 0 | 0 | 2.0 |
| 50 | 1 M | 0 | 1.6 |
| 60 | 2 M | 1 M | 1.5 |

*Anabaena* had started to grow in the lake. At a dose of 40 lb. per mil. gal. there was no odor, hot or cold, but when this amount was exceeded a musty odor was introduced. This happened in every test which was run. The effect on coagulation was also demonstrated. Table 5 shows what happened to the pig pen odor, caused by *Anabaena* after they had been killed by copper sulfate applied to the lake on August 26. At the 40 lb. per mil. gal. chlorine dosage there was no cold or hot odor.

The odor was not intensified by small quantities of chlorine in any of the tests mentioned. This is a very unusual occurrence. In Tables 6 and 7 is demonstrated what usually happens when raw Maiden Creek water is treated with small quantities of chlorine. On September 28, at the 10 lb. per mil. gal. dose the water had a very intense disagreeable odor not easy to describe. This was reduced to zero with 30 lb. per mil. gal.

The effect of super-chlorination on *Synura* is shown in the test run January 12, 1940. Not many colonies were present, but there were enough to impart a decided cucumber taste. The cucumber taste was changed to an intense, vile, fishy odor with a 10 lb. per mil. gal. dose, but all odor was completely destroyed at 40 lb. per mil. gal.

TABLE 6

*Effect of Chlorine on Odors, September 28, 1939*

| $Cl_2$ APPLIED | ODOR AFTER COAGULATION AND DE-CHLORINATION WITH FERROUS SULFATE | |
|---|---|---|
| | Hot | Cold |
| *lb./mil. gal.* | | |
| 0 | 2 M | 1 M |
| 10 | 5 d | 3 d |
| 20 | 2 d | 1 d |
| 30 | 0 | 0 |
| 40 | 1 M | 0 |
| 50 | 2 M | 1 M |
| 60 | 3 M | 2 M |

TABLE 7

*Effect of Chlorine on Odor due to Synura, January 12, 1940*

| $Cl_2$ APPLIED | $Cl_2$ RESIDUAL AFTER 2 HR. REACTING PERIOD | ODOR AFTER COAGULATION AND DE-CHLORINATION WITH FERROUS SULFATE | |
|---|---|---|---|
| | | Hot | Cold |
| *lb./mil. gal.* | *p.p.m.* | | |
| 0 | — | 3 Cu | 1 Cu |
| 10 | .08 | 5 f | 3 f |
| 20 | .40 | 2 f | 1 f |
| 30 | 1.35 | 1 f | 0 |
| 40 | 2.30 | 0 | 0 |
| 50 | 3.34 | 1 M | 0 |
| 60 | 4.37 | 2 M | 1 M |

No dip in the residual chlorine was found at any of these doses. The growth of *Synura* occurred in the early part of January, 1940, when ice covered the lake, making it impossible to dose the lake with copper sulfate. Since these growths are possible in the winter time, the Reading plant should be prepared to super-chlorinate at all times. Approximately 4,200 ft. from the plant a place, with available electricity, was prepared for the setting up of chlorinators for a plant scale experiment. From this point two conduits lead to the plant;

and these, when used at the present rate, allow a 2 hr. reacting period before the ferrous sulfate is applied. Two 300 lb. chlorinators for the experiment were borrowed and put into operation on August 15, 1939.

Super-chlorination was practiced from August to November. The results obtained in odor removal were similar to those found in the laboratory. Two growths of *Anabaena* in the lake occurred, and both times super-chlorination destroyed the resulting disagreeable odor. All other tastes and odors have also been reduced very close to zero.

The total bacteria count in the effluent from the settling basins was high before the super-chlorination treatment and became higher after that. Settling basins were cleaned, but this did not reduce the count in the settled water. It was evident that it would be better not to take all of the free chlorine from the water with ferrous sulfate; but to carry some to the settling basins.

An ammoniator was included in the original plant equipment, so that experimentation with ammonia treatment entailed no difficulty. Treatment, wherein ammonia enters the raw water several minutes before the ferrous sulfate, was started on September 14. On September 20, using 2 lb. of ammonia per mil. gal. the following amounts of chlorine were found with the neutral starch iodide test: (1) entering the plant (2 hr. after application of 40 lb. per mil. gal. $Cl_2$), 0.89 p.p.m. (2) entering settling basins, 0.35 p.p.m. (3) leaving the settling basins (8 hr. settling period), 0.32 p.p.m. On September 14, before the ammonia treatment was started, there were 1,100 bacteria per ml. in the settled water. On September 15, after ammonia treatment was started, there were only 5 per ml. and the bacteria remained low with the treatment.

## Amount of Ferrous Sulfate Needed for De-Chlorination

Theoretically 1.0 p.p.m. free chlorine should react with 65.33 lb. per mil. gal. of $FeSo_4 \cdot 7H_2O$. To clear up any question as to whether copperas alone will react to theoretical completion in these dilute solutions, the following test was run:

Chlorine was added to the raw water and left stand 4 hr. at which time it contained 7.73 p.p.m. free chlorine. The theoretical quantity of ferrous sulfate to combine with this quantity of chlorine is 505 lb. per mil. gal. Five hundred pounds per mil. gal. of ferrous sulfate were applied and stirred 15 minutes, filtered through glass wool. Chlorine was again determined and it was found that the

water contained .092 p.p.m. Since 5 lb. per mil. gal. less than the theoretical amount of ferrous sulfate was added, there would be left in the water .076 p.p.m. $Cl_2$. The difference from the theoretical, however, was only .019 p.p.m.

### Complaints From Chlorine in Distribution System

Even though the water now leaves the plant devoid of objectionable taste and odor, a close watch has to be kept on the distribution system. Since the new plant was started in 1935, ammonia has been applied before post-chlorination. Every time an attempt has been made to carry chlorine to the ends of the system, there have been complaints because of taste and odor in the city, where there is a good flow of water in the mains.

During the summer of 1938, the pipe lines from the pumping station to the city were being relocated. It was known definitely that on several occasions taste was caused from a coating applied to the pipes. Chlorine residuals around 0.70 p.p.m. were carried from the plant at this time and the water had no odor leaving the plant. It has been found that more free chlorine can be present without causing a chlorinous odor when softening, because of the high pH existing in the filtered water. Since the water is not recarbonated the pH is 9.0 to 9.5 in the water leaving the plant.

There were numerous complaints about taste and odor all through the summer and it was thought at the time that they were caused by the taste from the pipe coating. During the winter of 1938–1939 softening was not practiced. Then in the early summer of 1939 when starting lime ferrous sulfate treatment, it was attempted to carry the chlorine up to 0.70 p.p.m. again, but this resulted in complaints from the city. There was no taste or odor leaving the plant at the time and none as it entered the city. Since 0.70 p.p.m. residual chlorine leaving the plant, has not, over a period of several months, worn down the substances which combine with chlorine to cause taste and odor in the system, it would seem that this will have to be done over a long period of time using carefully controlled chlorine doses. At no time to date has chlorine been carried to the dead ends of the distribution system.

# Taste and Odor Control on Lake Michigan

***By Norton A. Thomas***

MOST of the cities located along the west shore of Lake Michigan utilize it for their municipal water supply. This large body of water is subject to contamination by industrial wastes, sewage, micro-organisms, etc., which continually cause taste and odor problems for the operators of water purification plants. The problems were far more acute during the summer of 1939 than they were in corresponding periods of previous years.

The experiences of those in charge of treatment of the different water supplies in this location were obtained by sending out questionnaires pertaining to the taste and odor problems and the methods of control used in the individual plants. Replies were received from twelve plants, and with one exception, the data submitted disclosed that micro-organisms were responsible for the objectionable characteristics in their supplies. One plant reported industrial wastes and sewage as the cause of high odor concentration in its supply. This plant is located on the lower end of the lake, south of Chicago, where the raw water is constantly contaminated with large quantities of such substances.

A tabulation of the data received from the different plants showed that the maximum raw water odor ranged from 10 to 100 as determined by the threshold method. For some water supplies these concentrations may not be considered unusual, but with Lake Michigan water, in the vicinity of the average intake, figures well below 10 are usual. Generally, the maximum odors that were due to micro-organisms occurred during either the latter part of June or the first part of July. Their character during this period was very obnoxious, similar to that of cod liver oil. In the plants where micro-organism

A paper presented on April 23, 1940, at the Kansas City Convention, by Norton A. Thomas, Chief Chemist, Milwaukee Water Works, Milwaukee.

counts were made at regular intervals, the protozoan, *Dinobryon*, was found to be present in the supplies in relatively large numbers, and was considered to be the chief cause of this odor. One plant reported the presence of about twenty times the normal number of the organism.

In most plants the treatment used for the elimination of these tastes and odors during the period was activated carbon. The maximum dosages varied between 22½ and 390 pounds per million gallons. The plant using the highest application reported a maximum threshold odor of 100 in the raw and an odor of 9 in the finished water, but was unable to apply larger quantities because the capacity of the feeding equipment was exceeded. At Glencoe, Ill., the treatment used is super-chlorination followed by de-chlorination with sodium bisulfite. This seemed to be successful, there being no complaints received from the consumers using the supply.

The recently completed water purification plant at Milwaukee, the largest plant on the west shore of Lake Michigan, was placed in full operation on July 2, 1939. On July 10 a sudden influx of microorganisms appeared in the water at the intake and caused a tremendous increase in odor concentration. At that time a maximum threshold odor of 45 was obtained on the water coming into the plant, considerably higher than any concentration observed previously. Just prior to this occurrence, it was below 5. Also, the filtered water going to the consumers up to the time had been free from any objectionable tastes and odors originating in the supply, so no special treatment methods in addition to those required in the normal filtration process had been used in the plant. The process employed consisted of coagulation with aluminum sulfate and lime, and prechlorination and post-treatment with chlorine and ammonium sulfate. The lime was added in relatively small quantities, as it was used merely to aid coagulation. The design of the plant permitted one to two hours for mixing, and four to eight hours for sedimentation, depending on the filtration rate. Pre-chlorine application was controlled to maintain a residual of 0.08 to 0.12 p.p.m. on top of the filters, and post-treatment to maintain a residual of 0.15 to 0.20 p.p.m. in the plant effluent. The sudden appearance of the unusual concentration of odor in the plant influent, however, made it imperative to start treatment for the elimination of the substances responsible.

The facilities provided for such treatment were mechanical feeders

for the application of activated carbon which could be applied either to the raw or settled water. When the high threshold odors were observed, the use of this chemical was included in the treatment process. The quantities of carbon required during the period, about one week, at times exceeded the capacity of the feeding equipment, so that it was necessary to apply a considerable amount to the water manually before it entered the mixing basins.

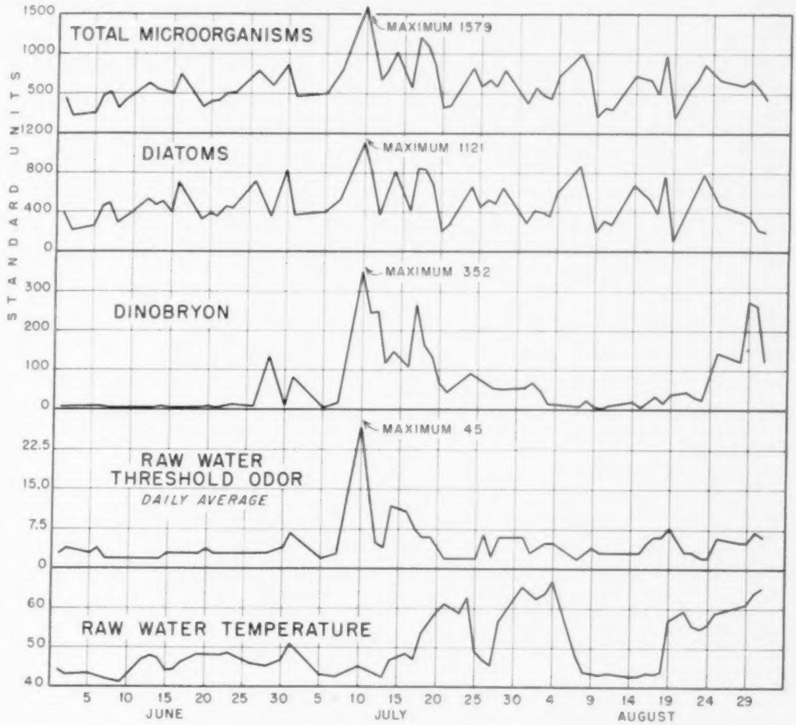


FIG. 1. Relationship between Micro-Organisms and Threshold Odor at the Milwaukee Water Works in 1939

Until then, threshold odor determinations had been made on different plant samples every four hours, but early experiences with the surface supply showed that more frequent control tests were necessary. With the introduction of treatment for the removal of tastes and odors the test was made hourly on the raw and plant effluent water. The control of the carbon application during the period was not obtained until 24 hours after the unusual odors were

noticed in the supply. Consequently, a considerable quantity of water was pumped into the distribution system that contained the objectionable characteristics, and resulted in many complaints from the consumers. After proper control was established, it was found that the application of approximately 1 p.p.m. of activated carbon for each threshold unit gave satisfactory results.

In connection with the plant treatment for the elimination of the tastes and odors in the Milwaukee supply, quantitative microscopical examinations were made daily on the raw water. The results obtained showed that the diatom group of organisms predominated in the supply, but during the period large numbers of *Dinobryon* were also found to be present, and were considered to be the chief cause of the abnormal conditions. The curves given in Fig. 1 show the relationship between the number of these organisms and the odor concentration of the raw water during the summer months of 1939. No definite relation between water temperature and threshold odor could be found. Later in the summer, the *Dinobryon* organism again appeared in relatively large numbers, but did not cause an appreciable rise in odor comparable to that found in July. This was probably due to the absence of the characteristic green substance in the cells that is ordinarily present during the growth period of the organism.

In conclusion it may be said that the taste and odor control problems in plants located on the west shore of Lake Michigan, north of Chicago, are due mainly to micro-organisms present in the supply. The experience at Milwaukee shows that the extreme fluctuations can occur very suddenly, requiring rigid control of the treatment, and if this control is properly maintained, a palatable water can be produced.

# Observations on Break-Point Chlorination

*By A. E. Griffin*

PRACTICAL experiences with break-point chlorination over the entire country including such widely separated places as Newport, R. I.; Tyler, Texas; Indianapolis and Anderson, Ind.; Ottumwa, Iowa, and at several plants along the Niagara River in New York State, indicate that the process is extremely valuable for the control of tastes and odors wherever encountered. Furthermore, these experiences re-affirm the earlier ideas regarding the value of break-point chlorination for the production of a water more nearly free from all gas forming bacteria than has heretofore been possible. Color improvement, coagulation economies, and possible removal of bacterial food are also indicated. Time may well show still further the full value of the process.

The amount of chlorine necessary to achieve these results in the majority of cases has not been excessive for the average quantity has seldom been more than 5 p.p.m. In a few isolated cases and for limited periods of time, however, applications as great as 35 p.p.m. have been used. Such extreme applications as used for a few days in February, 1940, at Ottumwa, Iowa, (110 p.p.m.) are not usual and may never again be duplicated. Mr. Brown's experience (page 1147 in this issue of the JOURNAL) in particular shows that for real results one should not be frightened at the thought of high applications.

Odors of phenolic, algal and decomposition origin have, on a plant scale, yielded to break-point chlorination. These results have been obtained in some instances by the addition of chlorine alone; in others by a combination of chlorine and activated carbon; while in a few instances de-chlorination with sulfur dioxide, sodium bisulfite, etc., has been necessary.

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A paper presented on April 23, 1940, at the Kansas City Convention by A. E. Griffin, Sanitary Engineer, Wallace & Tiernan Co., Inc., Newark, N. J.

Odors arising from waters grossly polluted with sewage are, for the purpose of this discussion, included in that class of odors above referred to as being of decomposition origin. Usually, considerable chlorine is necessary to reach the break-point in waters of this type. At Anderson, Ind., for instance, this past winter, during a period of low stream flow and consequent low dilution of sewage in the river, 35 p.p.m. of chlorine were used for a short time in order to produce a palatable and bacteria-free water. Similarly, at Indianapolis, Ind., a few miles downstream, as much as 18 p.p.m. chlorine were required on several occasions during the cold months. Incidentally, at Ottumwa, Iowa, where the unheard of amounts of 110 p.p.m. were added during the latter part of February, the stream consisted of nearly 50 per cent sewage.

For years, water works men have struggled with periodic taste difficulties resulting from the presence of phenolic wastes in the water sources. The use of activated carbon and chloramines has, in the past, been the favored way of meeting this problem. Break-point chlorination now enters this field and has already proven itself of great value, particularly along the shores of Lake Erie and the Niagara River. So far the applications in that area have been very nominal ranging from about 0.75 p.p.m. to approximately 2.5 p.p.m.

Few water supplies are entirely free from algae. As long as their number remain at a certain minimum, little trouble results. When, however, they begin to multiply beyond reason or when new types gain a foothold, taste and odor difficulties may develop overnight. It is not unknown for filter runs to be materially reduced as a result of such growths. Methods of control have included the use of chloramines or copper sulfate either alone or together. It has now been shown on a plant scale basis that chlorination to the break-point may frequently be an effective way of meeting these problems.

Under ordinary conditions where the water is relatively free from those types of pollution which add to the ammonia content, tastes and odors of algal origin have been effectively controlled by chlorine application ranging from 3 to 5 p.p.m. Where appreciable quantities of ammonia prevail, however, 15 p.p.m., or more, chlorine may be required to secure the desired results. In a few cases it has been necessary to chlorinate beyond the break-point and then de-chlorinate with sulfur dioxide, bi-sulfite or activated carbon in order to remove the odors completely. Activated carbon is particularly

useful for the removal of any slight trace of chlorine odor which may be left in the water.

Although color in itself has very little, if any, pathological significance, good water purification practice calls for its complete removal wherever possible. This is usually accomplished by flocculation and filtration. In many instances coagulation has been aided by pre-chlorination, but little attention has been given to the effect of chlorine alone on color. Recent experiments have shown that as much as 75 per cent or more of certain colors may be removed when chlorination is carried to the break-point. Now and then types of waters have been encountered where the color appears to increase sharply at this point. This increase, in most cases, however, has been only apparent, for in practically all cases where this has happened the color has been easily removed by filtration or has settled out as a floc upon standing. This phenomenon occurred at Ottumwa and Indianapolis during the past winter. In no case yet observed has chlorine set the color.

In general, the treatment of waters to the break-point will not appreciably change pH. It is only in the extreme cases that this phase of the treatment must be watched.

Wherever break-point chlorination is under consideration, it should be borne in mind that all waters react as individuals and that in all likelihood no two waters will produce exactly the same type residual curve. In fact, the shape of the residual curves on the same water may vary with the seasons, flood conditions, etc. In some waters the familiar "hump" and "dip" will be very pronounced; in others it will be barely discernible.

Laboratory work and plant experience now indicate that the free ammonia content of the water has a direct bearing, both on the shape of the curve produced and on the amount of chlorine required to reach the break-point. Thus, waters low in ammonia will produce, upon chlorination, curves which, are, except for a slight crook in the region where residuals first appear, nearly parallel to the dosage curve. Such a curve does not appear to have any break-point and is oftentimes difficult to interpret. This difficulty may be remedied by subtracting the residuals from the application and by plotting the results. Such a curve has been referred to by some workers as the "chlorine-assimilated" curve. The "break-point" on a curve of this type will be that point where no more chlorine is absorbed upon further addition.

As the ammonia content increases, so will the magnitude of the "hump" and "dip" and the amount of chlorine necessary to reach the break-point.

Intermediate between those waters which produce the "hockey stick" type and those producing the "hump" and "dip" types, are those of a less determinate character which will consume chlorine in a manner which results in an offset in the residual curve. Waters which have reacted in this way have been referred to as "offset" waters. Highly colored, soft, low pH, clear, algae-free waters, come within this group.

Several methods of control have been used although none has yet been developed which is universally applicable. These include the one developed by Norman Howard of Toronto, which depends upon the ammonia content of the raw water. Mr. Laux of Anderson, Ind., has developed a method based upon the speed of color development in ortho-tolidine (*see* Jour. A. W. W. A., **32**: 1027 (1940)). Mr. Calvert, of Indianapolis, is working on still another method which utilizes a double titrator.

# Developments in Taste and Odor Control

***By Henry F. Laughlin***

DURING the past years the subject of taste and odor control has received much justifiable attention, most of which has centered around activated carbon, so that mention of one inevitably brings to mind thought of the other. Other methods for controlling tastes and odors, however, have been tried and, in fact, are still being tried, and this constitutes a healthy situation that bespeaks a wide awake industry.

Probably the most important point in any investigation upon taste and odor control lies in adopting an absolutely neutral approach. Today, as never before, we realize the difficulty of being absolutely neutral in thought, but, at least we can set up experimental methods that eliminate what is popularly known as guiding the observer or leading him into what one believes should happen. The Spaulding Threshold Test has been found the most satisfactory of any so far tried. It involves two operators—one to prepare dilutions and the other to observe the odor—and is known as the "blindfold" method. A special adaptation of the threshold test for a single analyst can be used in such cases where the analyst can adopt an absolutely neutral attitude, but, in general, the two-operator approach is definitely recommended.

In studies on the use of super-chlorination for taste and odor control or removal, we have found that chlorine applied in dosages beyond the break-point produces an odor in some waters that is very difficult to correct. In some cases, extremely large dosages of activated carbon were required to remove this taste—in others, the dosage required was so great as to be practically prohibitive.

The following results were obtained utilizing a natural raw surface water:

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A paper presented on April 23, 1940, at the Kansas City Convention by Henry F. Laughlin, Research Chemist, Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Tyrone, Pa.

| Sample | Threshold No. |
|---|---|
| Raw | 16 |
| Chlorine past break-point (de-chlorinated) | 22 |
| 8 p.p.m. activated carbon on above de-chlorinated sample | 16 |
| 8 p.p.m. activated carbon on raw | 5 |

This observation has been reported elsewhere, and emphasizes the need of careful threshold tests on taste in any investigation on taste and odor control, such as the proper point for carbon application, or on other methods of control. It is well to try new ideas in the laboratory, checking results under all conditions of raw water. Inasmuch as the type of pollution will change from one time to another, it is necessary to examine different types of odor that may occur, and, at the risk of repetition, "use the strictly blindfold threshold test."

Two very careful investigators, W. J. Meaney of Cedar Rapids, Iowa, and E. C. Goehring, Chief Chemist of the Beaver Valley Water Company at Beaver Falls, Pa., have furnished the following information covering their experiences with the blindfold threshold odor test as a means of obtaining effective control of tastes and odors in their plants. In several respects these plants represent different types of treatment. For example, the Cedar Rapids plant is a softening plant, whereas Beaver Falls employs straight alum coagulation. But, while they differ in general type of treatment, they are in agreement as to the method of arriving at the proper solution of taste and odor problems.

At Cedar Rapids such problems occur at almost any time of the year, depending upon river conditions, e.g., in 1932, May was the month of extreme pollution, whereas in 1940, greatest pollution occurred in the months of January and February. Because of this, Mr. Meany continually checks the water at various points in his plant in order to have proper control of any situation. The principle types of pollution encountered at the Cedar Rapids plant include: (1) algae and microscopic organisms; (2) sewage and decayed material; and (3) phenolic taste in the tap water. The first two types come from the surface water supply, the source of the third was identified only after very careful check-ups had been made.

At the Cedar Rapids plant, the raw water is treated with lime and alum, mixed 1 hour and settled for 4 hours. Following this, more alum is added, and the mixing and settling time repeated. The filtered water is chlorinated. As evident from the above, activated carbon can be applied in a number of places including: (1) raw water; (2) lime mixing basin; (3) alum mixing basin; (4) on filters; and (5) combinations of the above.

In the ordinary control, activated carbon is added to the raw water. Application at this point results in very effective action inasmuch as it is followed by a 45-minute contact time while the water passes through a 30-inch pipe leading from the river to the plant proper. The choice of this point of application was not the result of a "hunch" or because it was convenient, or for some such similar reason, but followed considerable research which indicated that lime added for softening fixed the tastes and odors, and required greater quantities of activated carbon to produce a palatable effluent. Incidentally, this fixing may be somewhat similar to the fixing of color by lime treatment.

While lime was the contributing source of trouble in this case, there are definite case histories where ammonia, chlorine, alum and chlorinated copperas have either prevented a plant effluent from being as palatable as it should have been, or necessitated an increased dosage of carbon.

In cases of extreme taste and odor pollution, carbon is added to the raw water as well as to both mixing basins and on filters.

In the recent January and February, 1940, taste and odor epidemic, aeration treatment was also added at Grand Rapids, using a stand-by air compressor. This was particularly effective due to a high concentration of dissolved gases in the river water. The combination of active carbon and aeration made it possible to produce a palatable effluent during that trying time.

At Beaver Falls, Mr. Goehring has to handle quite a different type of pollution from that at Cedar Rapids. Beaver River, the source of water for this plant, flows through a highly industrialized and thickly populated section of western Pennsylvania. Here the greatest taste and odor troubles generally occur during the winter months. Formation of ice in the river prevents escape of odors to the atmosphere, and so concentrates the industrial and domestic sewage pollution at the plant.

The process used by Mr. Goehring for average taste and odor conditions is slightly different from that used for extreme pollution. For average pollution, the raw water is pre-chlorinated with from 0.6 p.p.m. to 4.0 p.p.m. chlorine, adding sufficient alum for coagulation. The water flows through a mixing chamber and a primary settling basin. Activated carbon is added in a secondary mixing chamber after which the water goes through a second mixing basin and to the filters. The filtered water is post-chlorinated.

Mr. Goehring always adds the carbon as near to the filters as the required dosage will allow, particularly in times of high turbidity in

the raw water. If less than 50 lb. activated carbon per mil. gal. is required to produce a palatable effluent, this is all added to the filters. Dosages from 50 to 100 lb. are applied in the second mixing chamber, and where the carbon required is over 100 lb. per mil. gal., application is made half-way through the primary mix. This allows time for the alum to floc, and more carbon reaches the filters.

Careful research by Mr. Goehring on points of carbon application has shown some very interesting facts:

(1) Alum coagulation and settling removes from 50 to 80 per cent of the odor in the raw water.

(2) Changing carbon application from beginning to half way through the primary mixing chamber saves about 15 to 20 per cent carbon.

(3) Addition of carbon directly on the filters is the most economical point at this plant.

(4) Using carbon in the secondary instead of the primary mixing saves 10 to 15 per cent of the carbon required.

(5) Use of pre-chlorination impairs the efficiency of carbon. Odor is increased and rendered more difficult to remove.

It would be preferable to eliminate the pre-chlorination, but this is impossible due to extreme fluctuations in coliform organisms which vary from 1,000 to 100,000 per ml.

It should be mentioned that Mr. Goehring has to treat difficult types of highly concentrated pollution. The carbon dosage will range from 50 to over 1,000 lb. per mil. gal., but the necessity for supplying an absolutely palatable water justifies these dosages of carbon.

During January, 1940, the average carbon dosage was 600 lb. per mil. gal. While this may seem like an extremely high dosage, Mr. Goehring states that the consumers did not at any time know that there was an epidemic of tastes and odors in the raw water. Although other methods of controlling tastes and odors have been investigated, activated carbon is the only one, so far, found successful in making the plant effluent palatable to the communities being supplied.

In conclusion, emphasis should be placed on the important point recognized by these investigators, namely, the value of conducting impartial taste and odor investigations.

# General Discussion on Water Purification

***By J. R. Baylis***

THERE is no line of endeavor where the wheels of progress have turned much faster than they have in water purification. The foregoing papers on this subject, which were presented at the Kansas City Convention, give accounts of some of the recent developments in this field.

Who would have been so bold, several years ago, to predict that 100 parts per million of chlorine could be added to water and the water later used for domestic purposes; or to predict that 1,000 pounds of activated carbon per million gallons would be used by any water supply to remove objectionable tastes and odors?

Palatable drinking water, regarded fifteen years ago as something to be desired, believed, ten years ago, possible in many supplies, is now a reality in most public water supplies. In the very near future there will be little or almost no unpalatable water served the public. Our dream seventeen to twenty years ago of better tasting water has come true.

I hope you will pardon reference to the past and will not construe the reference as self-praise or as a claim to leadership in this development, for my own contributions have been small compared with those of others. I was not the pioneer in the drive for more palatable water. The fight was well under way when I entered the field, but I have tried to help carry on the good work started by some of our very able water purification plant operators. I shall not mention names except that of Mr. Howard. It was through his early work at Toronto that I first became interested in taste and odor removal.

With your permission, I should like to quote several sentences

A discussion given on April 23, 1940, at the Kansas City Convention by J. R. Baylis, Physical Chemist, Bureau of Engineering, Dept. of Public Works, Chicago, Illinois.

taken from a paper presented before the American Society of Municipal Improvements, at Atlanta, Georgia, in 1923, entitled, "Let's Have More Palatable Drinking Water."

"Very few public supplies are satisfactory, in regard to taste, to all consumers. In many cities the amount expended for spring or bottled water is enormous. Part of this may be attributed to a mistaken idea that spring water is naturally better than any other water, but in most instances the reason is its palatableness.

"Changes in our mode of living and the vast amount expended for things that add comfort and pleasure to our lives justify the assumption that we are now ready for more progress in improving the palatableness of water. The health authorities have been satisfied as to the sanitary qualities; now we must satisfy the consumer as to its palatableness.

"Not long since, the superintendent of a filter plant made the remark that the water was all right when it left the filter plant and that it was not his fault if it got bad before it reached the consumer. It is hoped that this feeling is not shared by many filter operators. A cure for such feelings would be to construct dead-end mains so that the water for the filter operators would stand in the main at least a week before being used. One instance is recalled which resulted in the use of spring water by the operator. The filter operator should be interested in the water which reaches the consumer and not necessarily only that which leaves the plant.

"The great progress in water purification has been confined largely to the purity and the clarity. No universal program has been started to improve the palatableness of our water."

The advice to construct "dead-ends" for the water supplied to filter operators is still good advice.

Time will not permit, and it would be useless, to comment in detail on the papers mentioned. The experience at Milwaukee, with a supply receiving very little pollution and reasonably free from excess tastes and odors, is an illustration of what may happen occasionally from natural causes.

The experience of Appleton, Wisconsin, is another illustration of trouble arising largely from natural causes, although probably partially assisted by sewage and industrial wastes.

These are only two of a number of cities experiencing unusual taste and odor difficulties during the past year, caused largely from

natural conditions. The unusual condition at Ottumwa is, of course, a very, very limited condition.

The discovery of the break-point in chlorine residual opens a new line of thought which may greatly affect chlorination in the future. Can a polluted water supply be regarded as properly chlorinated until it has been treated beyond the break-point? I am inclined to believe that it cannot.

Will treatment to a substantial residual chlorine beyond the break-point kill all bacteria in water? I believe that it will, provided a reasonable period of contact is allowed. These remarks are based upon sterilization of the water.

Will treatment beyond the break-point produce satisfactory removal of taste and odor? The answer is that it will not in many instances, and probably will not in most instances; but it will produce from a little to considerable reduction in the taste and odor. It may lessen the amount of activated carbon required in some waters to produce the desired palatableness. When more than 500 pounds of activated carbon are required for a million gallons of water, the treatment becomes expensive.

A prediction for the future may be made. The manufacturers of chlorine should be satisfied, because more chlorine is going to be used. The manufacturers of chlorine equipment should be satisfied, because more chlorinating equipment will be required. The manufacturers of activated carbon should be satisfied, because more carbon is going to be used. Although some may believe there is going to be a slump in the carbon market, the use of activated carbon is going to increase, not decrease.

The health authorities should be satisfied, because all the bacteria in water are going to be killed. The public should be satisfied, because pure and more palatable water is going to be supplied to the consumer. The cost is going to be greater but the public will not object to a small increase in the cost of water if an improved product is produced.

# Discussion on Water Purification

*By Norman J. Howard*

THE tremendous variation in water purification and the various methods used in accomplishing the one end in which we are all so vitally interested illustrate best what a great problem we have.

I remember some fifteen years ago, when super-chlorination treatment was first started, I received a letter from Joseph W. Ellms of Cleveland, where at that time a mild chlorophenolic taste was giving some trouble. He wrote me on what he described as "the ambitious chemical experiment."

He said, "I admire the work being done, but I think you are starting at the wrong end. You should stop the cause of the trouble rather than treat the trouble when it has already developed."

We all realize that, if we could attack the initial troubles, then there would not be so great a problem as we have at the present time. The work done by the state boards of health has definitely eradicated much of the trouble with trade wastes, but the matter of controlling vegetable tastes and odors is an entirely different proposition. There are still many factors over which we have no practical method of control.

I have noticed a frequent reference to "chlorophenolic" taste. That may be a misnomer. Taste associated with a medicinal taste is called that. This should be entirely limited to odor created by trade waste pollution. There is a similarity between a medicinal taste and taste caused by the action of chlorine upon certain other vegetable substances present. I do believe in the literature it would be better to refer to a "medicated" taste rather than "chlorophenolic." There ought to be some definite phraseology which would more correctly differentiate the type of taste and odor which occurs.

The original study which resulted in the use of the word chlorophenol was based upon studies made of coal-tar derivatives. We made

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A discussion given on April 23, 1940, at the Kansas City Convention by Norman J. Howard, Director of Water Purification, Toronto, Canada.

an examination of twenty-eight byproducts derived from coal tar and found that of this number, six were capable of causing taste. Of the six, four were byproducts normally too valuable to waste. The other two, cresol and phenol, were not uncommonly found in trade waste effluents and sewage.

We examined our sewage and were able to isolate both of these substances (in the sewage) and with this knowledge we treated water containing a trace of chlorine with phenol and cresol and produced a characteristic medicated taste which we designated as chlorophenol and chlorocresol.

We next worked upon a method of treating water containing such combinations. We did a large amount of research work involving some three thousand experiments, treating them with varying quantities of chlorine. We found that as the chlorine dose was increased so the taste production increased with it.

After some two years experimentation we were prepared to abandon the whole study, until one morning after going in and tasting a sample which the previous night had contained a strong medicated taste, we found it free of taste. This gave us the clue we were looking for and we realized then that the time contact period was the solution to the problem.

We next investigated various combinations of chlorine, cresol and phenol and were able to draw a chart showing the definite time contact period necessary to treat water containing varying quantities of these trade wastes. We feel that the expression "chlorophenolic taste" should be confined to a taste produced definitely from trade waste substances.

I want to take this opportunity of mentioning two or three other men who must be regarded as pioneers in the treatment of taste and odor. Mr. Baylis forgot to mention his original suggestions concerning the use of activated carbon back in 1927 and 1928. The subsequent developments of powdered activated carbon by Mr. Spaulding have largely been the direct outcome of Mr. Baylis' suggestion that carbon should be used.

Then there was Mr. Enslow. I remember, when doing some early work, it was difficult to get away from Mr. Enslow. He was always on the job. In recent years he has made contributions of great value to many interested in water supply.

Again, Dr. Frank Hale was the first man in America to superchlorinate water. The New York City supply was super-chlorinated on a small scale for the prevention of the algae growths. Mr. Mc-

Amis of Greenville was the pioneer in ammonia-chlorine treatment. I think all of these men have played a tremendous part in the development which has reached present day proportions.

To the above discussion which was given orally at the convention, I should like to add some further thoughts which may be of interest to the reader.

In the JOURNAL for March, 1931, the writer presented a brief paper illustrated by a twelve-hour operating chart, which showed what was later developed and designated by William J. Orchard as "break-point chlorination."

Of recent date, the opinion has been frequently expressed that "taste disappears at the break-point." This may be true in some cases, but as a result of many years observation on the critical dose of chlorine necessary to correct taste, I am of the opinion that in many cases it will be found that the worst taste is produced somewhere between the top and the bottom of the descending curve, with the strong suggestion that the lowest residual point may often be found to approach the worst taste forming condition. In our experience, taste has been found to disappear sharply, immediately the curve starts rising.

In reply to a question as to his interpretation of the break-point, Mr. Griffin stated that in his opinion "the greater part of ammonia that was present in the water as free ammonia was destroyed." In studying this point as far back as 1935, R. E. Thompson, Chemist in the Toronto laboratories, found that if water containing free ammonia was super-chlorinated, it was necessary to remove the residual chlorine before estimating the ammonia. He found that if water containing both ammonia and excess chlorine was distilled, the amount of ammonia recovered depended upon the original application of chlorine. Under these conditions, the ammonia was reduced in proportion to the residual chlorine. If, however, the excess chlorine was first neutralised, practically no reduction in the free ammonia was noted. The chlorine applied in these experiments was taken up to as high as 4 parts per million. It may be that if the chlorine was greatly increased, some reduction in ammonia might result. Our experience does not support this theory, however, and I am rather sceptical as to the effect of chlorine on ammonia within certain well defined limits. Additional researches are being carried out, and it is hoped that they will be sufficiently complete to present at the next annual meeting of the Association.

# ABSTRACTS OF WATER WORKS LITERATURE

**Key.** **31**: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31**: 3: 481 (Mar. '39) indicates volume 31, number 3, page 481. Material enclosed in starred brackets, ★[ ]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A. Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British); I. M.—Institute of Metals (British).*

## STREAM POLLUTION AND CONTROL

**Industrial Wastes:** *Water Pollution.* Robert Spurr Weston. Ind. Eng. Chem. **31**: 1311 (Nov. '39). Problem of stream pollution has been much studied both here and abroad; though progress toward cleaner streams lagged during depression, interest is being revived. Streams must be used for best interests of all riparian owners and with due regard for rights and convenience of all. Waste treatment methods depend on self-purification capacity of receiving stream. Industrial pollution load of a community may far exceed domestic sewage load in B.O.D. Wastes from various industries differ as to nature, e.g., grease-containing, toxic, acid or alkaline, high B.O.D., unsightly, high in settleable solids, oily, taste and odor-producing, or occurring in batch discharges. Certain wastes interfere with natural self-purification processes. Chem. criteria are usually better than bacteriological in studying trade wastes since many troublesome wastes when discharged are sterile or nearly so. However, studies by U. S. P. H. S. indicate that waters to be rendered potable by chem. treatment and chlorination should not have over 500 *Esch. coli* per ml. Analytical methods show condition at time of sampling only, while study of plankton gives perfectly integrated index of stream condition. Much of self-purification in stream is accomplished by plant and animal life in it. *Legal Aspects of the Industrial Wastes Problem.* James A. Tobey. *Ibid.* **31**: 1320 (Nov. '39). Legal aspects of industrial waste problem include both private and public law, but mere invocation of law is no panacea for such technological and sociological maladies as industrial wastes, since besides legislative and judicial action, technical progress, education and financial aid are also necessary. Individual is entitled to suitable legal action for actual damages caused by a private nuisance, e.g., industrial wastes, but cannot proceed against public nuisance not directly affecting him. Property owner injured by industrial wastes may bring suit for damages, and if this is inadequate remedy, secure injunction against continuation of the nuisance. Failure to obey court injunction makes perpetrator of nuisance liable for contempt

and punishable by fine or imprisonment. Municipal corporations are legally responsible for nuisances created in such functions as operating sewerage system. Sanitary and drainage districts are similarly liable. A city may properly regulate amt. and type of wastes received by its sewers. Damages are not sought or awarded in case of public nuisances but nuisance may be enjoined or its abatement ordered by court of equity at behest of state or one of its political subdivisions, e.g., municipal corporation or health dept. State may also make perpetrator of nuisance liable to criminal action. Where public health is in immediate jeopardy, and resort to court action might create dangerous delay, public authorities can exercise right of summary abatement of the nuisance. On various occasions, individual states have brought actions against other states or industries in other states to restrain pollution of water. States may enact legislation to prohibit and control stream pollution by industrial wastes and delegate enforcement and administration to appropriate administrative agencies. Although such legislation has been enacted in most states, Feb. '39 report of Advisory Committee on Water Pollution (A. C. W. P.) of the Natl. Resources Committee considers laws on this subject in 33 states deficient in certain important respects. Standard state anti-pollution law should be prepared and adopted. Federal govt. is concerned only if navigable waters or interstate and foreign commerce are involved. Congress has in a no. of cases consented to compacts between two or more states for joint action in controlling pollution of waters flowing through several states. Author recommends establishment of federal agency to investigate pollution problems, advise states and coordinate efforts, without encroaching on states rights and rights of private industry. *Waste Problems in the Pulp and Paper Industry.* HERVEY J. SKINNER. *Ibid.* **31**: 1331 (Nov. '39). Nature of wastes from pulp and paper mills depends somewhat on process used but most important in stream pollution are waste sulfite liquor, produced by all sulfite pulp mills, and white water, containing fibers, common to all pulp and paper mills. They render streams unsightly, use up dissolved oxygen, thus harming fish life and preventing natural purification of incidental pollution entering stream, and render water unsuitable for sanitary and industrial purposes. Strict application of existing state laws on stream pollution would drive many industries out of business; leniency has been the rule except where pollution is obnoxious or dangerous to health. This leniency will not last indefinitely, and industries are already taking steps to abate pollution. In sulfite process approx. ½ the original wood, chiefly lignin, is discharged as waste, in U. S. about 7,500 tons per day. Most attempts to utilize waste after evaporation have failed due to excessive cost. Process developed by Guy C. Howard of Seattle at Marathon Paper Mills Co., Rothschild, Wis. is most outstanding development. In main process, fractional precipitation with caustic lime reagent produces a calcium sulfite product used for making fresh cooking acid for re-use in plant, solid organic product containing lignin, and effluent with B.O.D. 80-90% lower than original liquor. Depending on local conditions, main process will show profit or just make expenses. From lignin product obtained in main process, tanning preparation, portland cement fixer, reagent for boiler feed water treatment

and for ceramics, and lignin plastic products are being made on commercial scale. Also, more than $\frac{1}{3}$ of vanillin used in U. S. is made from this lignin product. White water contains appreciable amts. of fiber; survey in '27 indicated losses at 6 to 7 million dollars, though amt. now is much lower. Losses should not be over 1% of production, compared with 15-20% in some cases in earlier years. Re-use of white water in closed system decreases stream pollution and minimizes amt. of water used. Although pulp mills offer less opportunity for decreasing amt. of water, improvement can be effected by using countercurrent washing for cooked stock and re-using white water as possible. Continued re-use of white water requires minor changes in certain operations and increased temp. of water promotes slime formation, which may

TABLE 1

*Data on Wastes in Fermentation Industry*

| TYPE OF WASTE | SOLIDS | 5-DAY B.O.D. | USUAL TREATMENT |
|---|---|---|---|
| | % | *p.p.m.* | |
| Brewery | 3.0 | 10,000-25,000 | Yeast recovery and sewage treatment processes. |
| Yeast plant | 1.0 to 3.0 | 7,000-14,000 | Digestion followed by trickling filters. |
| Molasses fermentation in industrial alcohol still | 5.0 | 22,000 | Evaporation and incineration. Ash has 33% $K_2O$ and is used in fertilizers. |
| Acetone-butanol still | — | 7,000-11,000 | Anaerobic digestion followed by aerobic stabilization. |
| Distillery slops | 4.75 to 6.0<br>2.5 to 3.0 soluble | 15,000-20,000 | Screening, evaporation of liquid, for poultry feeds. |

be controlled by chloramine treatment. Although installation of closed system requires careful planning and some expense, materials recovered may far more than pay cost. *Waste Problems in the Fermentation Industry.* C. S. BORUFF. *Ibid.* **31**: 1335 (Nov. '39): Fermentation industries were formerly among worst offenders in adding heavy pollution to sewage treatment plants or streams but newer plant methods conserve raw materials and reduce pollution load. Most whiskey distilleries now return 15-35% of fermented and distilled mash to fermentation process in place of part of the water, and reuse of cooling waters produces economies. Effect of present practice is shown in Table 1. In addition, some small amts. of certain wastes can be developed as sources of vitamins $B_1$, $B_2$ and G. Potash recovery is profitable only when potash prices are high. Screening distillery slops produces 8 to 10 lb. of dried

feed per bu. of original grain ground; with subsequent evaporation, recovery is about 18 lb. In process used at Hiram Walker and Sons, Inc., centrifuges remove solids before multiple effect evaporation, and feed from waste is sold at profit. More work is needed on distillery slop treatment, especially from rye. Even small amts. of fermentation wastes interfere in activated sludge plants, but optimum conditions for biological treatment of fermentation wastes have been worked out and successfully used. *Industrial Wastes from the Equipment Manufacturers' Viewpoint.* C. L. KNOWLES. *Ibid.* **31**: 1338 (Nov. '39). Handling of various wastes uses physical (metallurgical), chemical and biological methods. Problems in waste disposal may arise from: (1) War Dept. objections to blocking of navigable streams, e.g., sand, coal; (2) city or state demand for color or turbidity removal, e.g., oil, dyeing or paper wastes; (3) health dept. requirement for B.O.D. reduction or elimination of bacteria, e.g., distillery, packing-house, milk plant or pulp or paper mill wastes. A variety of equipment is required in various processes. Very often, sedimentation is first treatment step; thickener is used for metallurgical processes; and clarifier and flocculator for sanitary processes. Filtration of thickened solids is frequently necessary, and incineration equipment is available for filter cake where needed. If preliminary screening is needed, bar and rotary screens, detritors and classifiers are available. The "ADKA Save-all" is used for recovery of light particles, e.g., paper fibers by flotation process. Flotation is also used for mineral wastes. Clarifier effluent may require aeration for B.O.D. reduction. Underflows may be digested or passed through trickling filters. Such equipment may be combined in various ways. Agitators and aerators are available for metallurgical and sanitary processes. Where chem. treatment is needed, accurate feeders and proportioners are available, minimizing labor costs. 24 illustrations of equipment. *Waste Problems of a Chemical Company.* I. F. HARLOW. *Ibid.* **31**: 1346 (Nov. '39). Wastes of Dow Chemical Co., Midland, Mich., are divided into 5 groups: (1) Non-hazardous. Barometric condenser water only intermittently contaminated by brines. These have little effect, except at very low flow, on receiving stream, the Tittabawassee R., which flows into Saginaw R., which, in turn, empties into Saginaw Bay. Sodium hydroxide may injure fish for 20 rods below entrance of effluent into river. (2) Brine. Daily, 23,600 bbls. of brine must be disposed of, after removal of bromine only. Too much for daily release into river. Return of brine to underground formations has not been successful. Brine is impounded for release during high-water runoff periods. River varies from 200 to 6,800 sec.-ft. flow. Storage is available for over 2-yr. excess brine production. Saginaw Water Works, which would be affected by brine flow, has raw-water storage protected by steel gates. Bay City has res. with 1 wk. capacity. Brine flow has been traced by over 10,000 electrometric determinations of chloride concentration in streams and bay. Brine releases are not made during mfg. season in beet sugar factories along stream below, and other industries are notified before each release. Concentration during releases is kept below 5000 p.p.m. at Midland to assure not over 1000–1500 p.p.m. at mouth of Saginaw R. (3) Taste and odor-producing wastes. These include products from cracking of oils and e.g., nitrobenzene and mercaptan, but not phenol or related compounds. A 65-acre pond is used for

storage of scrub water from cracking plants; after storage it is pumped back for reuse. Oil and tar are accumulating and will necessitate a new pond or burning of the accumulation. (4) Phenol and e.g., chlorobenzene, aniline and salicylates. Since '27, phenol-polluted plant effluent has been impounded but taste troubles result even when wastes were discharged at high river flow. Plant produces 200,000-500,000 g.p.d. of waste having over 5 and up to 500 p.p.m. of phenol, and 10-15 million g.p.d. having usually 1 to 2 p.p.m. of phenol. Of various methods tried, biological has been most successful. Strong and weak wastes are mixed, adjusted to pH 6.8 with lime, and pumped to a depth clarifier. Effluent flows by gravity to 2 trickling filters, and sludge is settled. Liquor from sludge runs to strong phenol storage. Trickling filters have 10′ bed of blast-furnace slag. Filter rate is about 16,000,000 gal. per acre per day with ave. phenol content of 13 to 30 p.p.m. Effluent (0.4 to 3.0 p.p.m. of phenol) flows to 31-acre pond, from which it flows to river with less than 0.05 p.p.m. of phenol. Temp. of feed to filters must be 70°F. for this filter rate; lower temp. necessitates lower rates and below 50°F., practically no action occurs. Waste can be seeded with domestic sewage but river water (containing soil bacteria) is equally successful and is being used. (5) Sediments. Plant effluents containing appreciable amts. of turbidity are settled through ponds several ft. deep and covering 42 acres. Work is in progress on disposal of wastes which cause unsightly precipitates when mixed with each other or with river water. (6) Atmospheric pollution is prevented when possible. Odors, e.g., hydrogen sulfide from storage ponds, may be a nuisance in warm weather. *Biological Processes for Treating Waste.* A. M. BUSWELL. *Ibid.* **31**: 1349 (Nov. '39). Primary object of waste treatment processes is prevention of oxygen deficiency in streams by removal of oxidizable organic matter before discharge of waste into stream. In biological treatment, bacteria transform organic matter into insoluble gases (fermentation) or solids (bio-precipitation). Anaerobic bacterial process is much cheaper than aerobic per lb. of organic matter stabilized but it is impossible to produce effluent comparable to that yielded by aerobic treatment and cost of anaerobic treatment per lb. of organic matter increases as concentration of waste decreases, due to larger tankage required. Anaerobic effluent is usually dark and rather foul with B.O.D. of several hundred p.p.m., but if high dilution is available, anaerobic treatment may suffice. B.O.D. reduction may be 75-90%. There is no upper limit of concentration in anaerobic process. Aerobic treatment is carried out in trickling or sprinkling filters or activated sludge tanks. Effluent is of high quality, with low color and B.O.D. Limitations are inability to treat liquids of high concentration and inability to handle coarse solids. By recirculating effluent with raw waste, more concentrated wastes can be handled, especially on trickling filters. Aerobic treatment can be used on effluent from anaerobic process. Proper seeding and dilution of digestion mix. makes possible greatly increased loadings. This combination treatment with special attention to seeding, temp. control, dilution, etc. has produced high-quality effluent from distillery waste containing about 3% solids. Special tank is required for anaerobic treatment of coarse solids, e.g., paunch manure, to enable material to be fed conveniently and undigested material removed. Drum is rotated or inverted at least twice daily. Phenols are decomposed by both

aerobic and anaerobic action; 50-100 p.p.m. of phenols have been treated without interrupting operation of the bacterial process. All types of organic wastes are amenable to biological treatment. Complete purification is feasible and from certain wastes anaerobic process yields a valuable quantity of methane as a by-product. *Treatment of Liquid Wastes from the Textile Industry.* C. R. Hoover. *Ibid.* **31**: 1352 (Nov. '39). These wastes usually average only 0.05 to 0.2% impurities, though wastes from special operations may contain 1 to 3% of organic matter. Ave. B.O.D. of 16 wastes studied was 618 p.p.m. Suspended matter accts. for 20% of B.O.D. of ave. textile wastes. Dilution is first recourse and last resort in all waste treatment but present trends indicate that it must decrease in future. Segregation of strong and weak textile wastes is not always practicable. Equalization (mixing of wastes which will react with each other) is cheap and is successful preliminary in treatment of many wastes; it allows dilution, regulation of flow, neutralization and precipitation. Storage accomplishes cooling and chem. and biological action. Aeration of textile wastes accomplishes physical, chem. and biological action. Mechanical or phase separation includes sedimentation, dialysis, etc.; it allows recovery of by-products such as grease, alkali and dyes. Coagulation with ferric and aluminum sulfates, etc. lowers B.O.D., removes color, suspended solids and toxic materials, and regulates pH. Other chemicals used include lime, acids and activated carbon. Disposal of coagulated sludge is a major problem; general practice is to reduce sludge to approx. $\frac{1}{10}$ its vol. on a drying bed, then remove to dump. Part of fresh sludge may be effectively reused to decrease chem. dosage needed. Biological treatment of textile wastes is more extensively used in Great Britain than in U. S.; best aerobic method is by intermittent or trickling filters. Textile waste when applied to intermittent sand filters causes clogging within a few months. With other filter media such as coke ballast, B.O.D. reduction is largely due to retention of organic matter in filter rather than to biological oxidation. Though this may be sufficient for some wastes, oxidation can be accomplished by mixing neutral and equalized textile waste with 80-90% of domestic sewage before applying to trickling filter. Sulfur dye waste, one of most concentrated and difficult dye wastes to treat, can be purified by activated sludge process when well diluted with domestic sewage. With equal parts of domestic sewage and of woolen and hat factory wastes, in anaerobic thermophilic digestion at 55°C. with slow surface stirring, fibers and hair were completely destroyed and normal sewage sludge was produced. Experiments show that textile waste retards but does not prevent sludge digestion. For a cotton piece-goods-waste treatment plant described, treating 250,000 g.p.d. with copperas and lime followed by lagooning of sludge, cost is estimated at 8¢ per 1,000 gal. at normal capacity; for a 300,000 g.p.d. chem. precipitation plant described treating rayon finishing wastes, cost would be 9¢ per 1,000 gal. Though natural-fiber textile industry is not notably prosperous, is not expanding and is highly competitive, waste treatment must be considered legitimate expense. Textile manufacturer should have assistance of community in disposing of his wastes if he applies sufficient treatment to make them comparable to domestic sewage in concentration and ease of treatment. Work is needed on: simple and cheap treatment methods of equalization, aeration and mechanical separation; applica-

tion of biological action; cheapened and improved use of chem. coagulation; and development of recovery processes to reduce pollution rather than to increase profits. Manufacturers will profit by careful study of waste control and elimination with sound chem. and engineering advice, cooperation with trade organizations and pollution control agencies, and removal of trade wastes from natural waters, not only to benefit recreational and domestic water users, but also other industrial users and ultimately all industry. *Waste Problems in the Nonferrous Smelting Industry.* ROBERT E. SWAIN. *Ibid.* **31**: 1358 (Nov. '39). Sulfur dioxide ($SO_2$) is discharged in enormous quantities in flue gases from smelting operations the world over. Damage caused by $SO_2$ and economic losses suffered in industry itself have led to extensive $SO_2$ recovery installations, utilizing various methods and producing sulfur, sulfuric acid, ammonium sulfate and marketable $SO_2$. Arsenic occurs frequently with sulfur in ores and escapes in flue dust and gases, one plant having discharged daily 25 to 30 tons of very finely divided arsenic trioxide until electrical precipitation methods completely eliminated this loss and contamination. Cadmium and thallium are recovered from zinc smelter flue dust and electrolytic plant residues and used commercially. Other rarer metals such as bismuth, antimony, indium, vanadium, selenium and tellurium are similarly recovered. In some metallurgical processes, refuming of slag reduces metal losses, e.g., lead and zinc. Slag is also a new material for manufacture of mineral wool for insulation, refrigeration and air conditioning. New flotation processes prevent loss of small concentrations of molybdenum associated with lead and previously lost. Iron pyrites is now separated from other sulfide ores to reduce load on smelting operation and reduce $SO_2$ emission. Cottrell electrical precipitation process has been of enormous value to smelting interests in eliminating toxic and noxious mists and fumes, rarer metal losses and enormous dust losses of common metals, etc. Smelting industry in last decade has become research and by-product conscious, thus aiding conservation and eliminating bitter litigation. *Waste Problems in the Petroleum Industry.* J. BENNETT HILL. *Ibid.* **31**: 1361 (Nov. '39). All petroleum fractions have fuel value and none is a waste problem. However, refinery waste waters must be cleaned of oil until concentration is too low to show surface iridescence. One pt. of oil will cause strong iridescence over area of about 10,000 sq. ft. of water. Gravity separators making use of principles of low-velocity uniform distribution, film rupture and coalescence and continuous skimming of oil give effluent containing only 10–15 p.p.m. of oil. Oil emulsions, if present, are treated by acidification and coagulation with aluminum or calcium salts, or by heating, addition of a hydrophilic colloid or by electrical means, depending on type of emulsion. Most important chem. waste problem is acid sludge from treatment of oils with sulfuric acid. Recovery of acid is practicable and is commercially used. Spent soda from treatment of raw gasoline contains sodium sulfides, mercaptides and phenolates. It may be treated with weak recovered acid and the hydrogen sulfide and other evil-smelling compounds steamed or boiled out. All crude oils contain more or less hydrogen sulfide; this must be removed to avoid corrosion even where recovery is not desired. Removal is usually by a reversible absorbent. Hydrogen sulfide production in these plants probably totals over 150 tons per day. It is generally burned as fuel or

converted to sulfuric acid. Spent fuller's earth from oil-decolorizing operations is usually reactivated by burning and is re-used. When exhausted, it is substantially oil-free and can be used as a fill or inert diluent for various products. Lead sludges from sweetening of gasoline with sodium plumbite are now almost universally reactivated for re-use. Lighter hydrocarbons, previously burned as refinery gas, are now more profitably marketed as bottled gas or converted to various by-products, e.g., isopropanol, glycerol and ethanol. *Waste Problems of the Iron and Steel Industries.* WILLARD W. HODGE. *Ibid.* **31**: 1364 (Nov. '39). Rapid growth of the iron, steel and associated by-product coke industries has brought problems in the utilization and disposal of waste materials. Fairly satisfactory treatment and utilization processes for certain wastes have been in operation for years but improvements are needed. Hydrogen sulfide was formerly passed over iron oxide to convert to iron sulfide, which was dumped, producing another objectionable waste product. Now it is recovered as sulfuric acid, hydrogen sulfide or sulfur, the recovery of sulfur alone being 35,000 tons per yr. On the ave., approx. ½ ton of blast-furnace slag is made per ton of pig iron produced. Blast-furnace slag production for '37 is calculated at 18,500,000 tons, largely calcium aluminum silicates. Utilization of 7,900,000 tons of slag was reported in '38, 50% for road bldg., 20% for railroad ballast, 20% for concrete construction and 10% for misc. uses, including trickling filters, roofing, sweetening acid soils and manufacture of mineral wool. Iron-containing dust has been settled and scrubbed from flue gases for 40 yr.; about 150 lb. of flue dust are made per ton of pig iron produced. New developments make possible compacting and re-smelting of this waste. By-product coke works have largely superseded bee-hive ovens; atmospheric pollution from latter has been eliminated, $100,000,000 worth of by-products conserved and yield of coke per ton of coal increased 5 to 10% but new problems in disposal of liquid wastes have been created. Many by-products are produced from coal tar but possibilities have not been exhausted. Although only small quantities of phenols are present in waste liquor from by-product plants, tastes and odors produced in receiving streams caused great nuisance in water supplies. Ohio R. cooperative investigation begun in '24 initiated recovery and disposal methods resulting in marked improvement in stream conditions. The waste pickle-liquor problem is of world-wide significance. In U. S., production is estimated at 500,000,000 to 800,000,000 gal. per yr. Liquor from batch picklers contains 0.75 to 2% free acid (usually sulfuric) and 4 to 30% ferrous sulfate; liquor from continuous strip picklers contains 3 to 7% free acid and 12 to 16% ferrous sulfate. Problem of disposal or use of waste pickle liquor has been studied for over 50 yr.; $10,000,000 is spent annually in all types of investigational work. Attempts have been made to dispose of liquor by pumping into underground formations, abandoned mines, oil and gas wells, etc., by evaporation in ponds, by pumping onto sand or gravel sumps located near large bodies of water, or by discharge into sewers emptying into rivers, lakes or tidewaters. In general, serious objections have arisen to each of these methods. Various neutralization methods have been used to eliminate acid without recovery of by-products but these add significantly to cost of manufacturing process. Usable by-products obtainable include copperas, sulfuric acid, ferric sulfate, electrolytic iron, iron oxide for neutralizing acid, or for

pigment or polishing rouge, "Ferron", an interior construction material composed of iron oxide and calcium sulfate, ammonium sulfate, ferrous sulfate, etc. Over 40 processes are discussed for producing these substances. In some cases liquor remaining from process (e.g., crystallization of copperas) can be re-used as pickle liquor. Equipment for waste liquor treatment is expensive to install and maintain because of corrosion. Marketing of by-products is in some cases a problem. Supply of copperas, leading by-product, far exceeds demand, though new uses could be developed and present ones expanded, notably in water and sewage treatment. Chlorinated waste pickle liquor and lime, or sometimes alum, is giving satisfactory results at Akron, Ohio, water works with marked economy over methods previously used; and many other cities use iron salts obtainable from spent pickle liquors. Better equipment and increased knowledge of chem. phenomena involved have increased use of chem. precipitants in sewage treatment. The ACWP estimated that in Aug. '38, 73,000,000 people in U. S. were served by sewers. Sewage from approx. 19,000,000 pop. received primary treatment, from 20,700,000 more secondary treatment, and sewage from remainder, nearly ½ total sewage, was discharged untreated into receiving waters. In spite of large total of mine and manufacturing wastes, domestic and municipal sewage is still probably largest and among worst of stream pollution sources. In '33, annual pollution of Ohio R. was estimated at 3,000,000 tons of sulfuric acid, including 2,700,000 tons from coal mines. Total from abandoned mines was set at 1,000,000 tons; mine sealing program should reduce this by 600,000 tons. Costs for reasonable abatement of remaining water pollution in the U. S. as calculated by ACWP are: (1) capital costs to treat municipal sewage, $1,000,000,000, and annual operating costs, $15,000,000; (2) complete sealing abandoned coal mines, $12,000,000, control of anthracite wastes, $40,000,000, min. treatment of oil field brines, $100,000,000; (3) treating industrial wastes where practicable, capital costs $900,000,000, operating and fixed charges $225,000,000 per yr. In certain bills before Congress, stream purification projects outlined would cost estimated $5,000,000,000. ACWP estimates that coordinated program for abatement of major pollution of water bodies of U. S. would require 10 to 20 yr. for accomplishment. Though many waste problems have been solved, past experience shows that solution of waste problems often requires technical developments beyond those needed to install process creating them. Present research and development work on waste pickle liquors is mainly improvement of present processes and development of new ones, working out of uses for by-products recovered and possible development of other methods than acid pickling for cleaning iron and steel. These problems are being worked on by iron and steel plants, chemical companies, universities, federal, state and municipal laboratories and Mellon Institute. Congressional act to set up funds for cooperative research between states, cities and industries on sewage and industrial wastes would probably be another important step in right direction. To conserve irreplaceable national resources, abatement of all unnecessary stream pollution and recovery of valuable by-products from waste materials are both of vital importance in continued development of our country. Bibliography of 139 titles.—*Selma Gottlieb.*

**Ohio River Pollution Survey Methods and Progress to Date.** H. W. Streeter and E. S. Tisdale. Munic. San. **2:** 17 (Jan. '40). Practical purpose of survey is to determine source and extent of pollutive substances being deposited directly or indirectly into the Ohio R. and tributaries; also the most feasible method of correcting such pollution (pol.). Lab. studies and field surveys are being made by the U. S. P. H. S. Streams Pollution Div. at Cincinnati, Ohio. Hydrometric studies are in charge of the U. S. Army Engineering Corps. A special activity connected with the survey has been an epidemiological study of water-borne diseases. Information relative to sewage and industrial waste pol. is obtained in cooperation with State Depts. of Health. Present results indicate 2 zones of relatively high pol., one from Huntington, W. Va., to Portsmouth, Ohio; other from Cincinnati 60 mi. downstream. It has been found that Federal financial assistance has given impetus to improved methods of sewage disposal. The survey involves 204,000 sq. mi., 14 states, approx. 18,440,000 pop., and the most important agricultural and industrial sections in the U. S. If completed, it will constitute the most detailed and extensive pol. study undertaken in the world.—*Ralph E. Noble.*

**Coastal Waters Pollution Interests Californians.** *Staff Report.* Munic. San. **10:** 589 (Dec. '39). A symposium on problem of pollution (pol.) of navigable and interstate waters was presented at joint meeting of the Calif. League of Municipalities and the Calif. Sewage Wks. Assn. While pol. problems are widespread, present Federal laws pertain to navigable streams. Two Congresses have considered pol. legislation but without action. Act of 1899 made pol. unlawful by any wastes other than flowing in liquid state from streets and sewers. Oil Pol. Act of '24 prohibited oil discharge from any vessel into or upon U. S. coastal waters. The Govt. assumes its jurisdiction any distance at sea to assure no pol. Army engineers attempt to prevent pol. rather than apprehend offenders. Enlisted cooperation has been successful. Fish-canning industries have been offenders but self-imposed corrections have resulted in profit from by-products. Current admin. control according to Natl. Resources Committee, may be classed under 4 general methods: (1) persons suffering damage may be compensated by sueing and proving extent of such; (2) state laws are in effect authorizing officials to take action against pol.; (3) one interstate authority is functioning, and several other compacts are in formation; (4) Fed. Govt. regulates pol. of coastal waters by oil, and navigable waters by substances which impede navigation. In addition, the U. S. P. H. S. exercises an indirect control over water pol. and shellfish area contamination. Natl. Resources Committee recommendations include: strengthening state laws; pol. studies by Pub. Health Service; and Fed. financial assistance, upon specific recommendation of a Fed. agency, preferably U. S. P. H. S.—*Ralph E. Noble.*

**Pollution Under Ice.** *Part of Staff Rept. of N. Dakota Water and Sewage Conf.* Gilbert Groff. Munic. San. **10:** 588 (Dec. '39). Ice covered streams in north present different pollution problem than those in south. Critical period in latter is in summer when temp. is high and dissolved oxygen low. In former, it occurs after ice formation, especially with slow moving pollution.

In a few wks., dissolved oxygen decreases from saturation to zero. To simulate actual conditions for study, zero degree incubation is advisable for B.O.D. determinations. Oxygen depletion from ice covered streams follows no set rule.—*Ralph E. Noble.*

**Water Supplies and River Pollution. Annual Report of the Water Pollution Research Board for Year Ended June 30, 1939.** Surveyor (Br.) **97**: 21 (Jan. 12 '40). Greater vigilance required in protecting sources of water supply from pollution due to war conditions involving movement of large numbers of people. Research supervised by Board includes treatment of water for domestic and industrial purposes, treatment and disposal of sewage and industrial wastes, and stream pollution. Work has shown that satisfactory base-exchange substances for water softening can be obtained by treatment of fuller's earth, which occurs in large amounts in Great Britain. Corrosive action of water on metals has received special study, particularly with respect to the solution of lead and its effect on public health. Concentration of lead of even $< 0.5$ p.p.m. is considered dangerous. Lead may be removed by passing water through limestone, marble, or similar substances. Bacterial investigations of lakes and streams have been conducted to learn factors which govern abundance and types of bacteria in fresh water. Methods for treatment of dairy wastes were tested in 2 large-scale plants. Results now make it possible to design plants for economical treatment of all dairy wastes. Successes suggested desirability of tests on treatment of domestic sewage by similar double-filtration processes. In addition, expts. have been continued on activated sludge process, including effect of temp., amount of return sludge and acidity or alkalinity of mixed liquor.—*H. E. Babbitt.*

**Modern Concepts of Stream Pollution from Paper Mills.** C. L. SIEBERT. Paper Tr. J. 109 ('39). Describes steps taken during recent years to decrease pollution of streams by industrial wastes, with special reference to effect on pulp and paper industry. Author considers it practicable to keep losses of fibre in white water from paper mills below 0.5% of total wt. of product, and total vol. of wastes below 10,000 gal. per ton of product. Table of results given showing large reductions in pollution after methods of control had been introduced; most satisfactory results were obtained with system of recirculation of waste waters within mill, but chem. coagulation and sedimentation may be successfully employed. Problem of treatment of sulfite waste liquor is discussed and details are given of a plant which is expected to eliminate 85% of previous pollution. Disposal of waste waters from de-inking processes and from rope and rag digesting plant is also discussed.—*W. P. R.*

**Work of the Water Pollution Research Board.** ANON. Nature (London) **144**: 718 ('39). Statement given, prepared by R. Robertson, chairman of Water Pollution Research Board, for presentation to Conference of Delegates of Corresponding Societies at the Dundee meeting of British Assn. for Advancement of Science. Pollution due to effluents from beet-sugar factories can be avoided by treating effluents on biological filters; it is practicable to avoid discharge of effluent by re-use of water. Effluents from milk factories can be purified by

biological filtration, using two filters in series with periodic change in sequence of filters, or effluents may be treated by activated sludge process. Studies carried out on Tees R. included investigations on chem. composition of river water, on animal and vegetable life of river, and on seasonal changes affecting self-purification of river; similar investigations were made on estuarine waters. Poisoning of salmon and sea-trout smolts was shown to be due to cyanide discharged into river in effluents from coke-ovens; methods of avoiding this poisoning have been suggested. Board has carried out investigation on effect of discharge of crude sewage into Mersey R. on amount and character of deposits in estuary. Found that vol. of estuary is subject to periodical changes, but that alleged decrease in vol. of estuary could not be attributed to discharge of sewage into river. Effect of various substances used in base-exchange process has been examined, determinations have been made of efficiency of such substances, and it has been found that artificially prepared resins can be used to remove acidic and basic radicals from water. Study of plumbo-solvency has been made. Expts. have been made to elucidate the mechanism of methods used for treating sewage.—*W. P. R.*

**Aspects of Governmental Policy on Stream Pollution Abatement.** Herman G. Baity. Am. J. Pub. Health, **29:** 1297 (Dec. '39). Difference of opinion exists among interested agencies as to best method of abatement of national pollution problem. Use of natural water course for reception and disposal of liquid wastes held as necessary and legitimate as its use for any other purpose, subject to definite limitations. Proper balance of stream uses different for every stream, and for each, depending upon conditions, there is one combination which is most logical and economical. 73 (56% of total) million people of U. S. served by public sewerage systems, discharging daily approx. $5\frac{3}{4}$ billion gal. of liquid wastes—represents however, less than $\frac{1}{2}$% of ave. daily flow of streams of country. 39,700,000 served by some type of sewage treatment works treating roughly $3\frac{1}{4}$ billion gal. per day with $2\frac{1}{2}$ billion gal. being discharged untreated. Other wastes also important to pollution problem. Special committee to National Resources Com. estimates further cost of treatment works for reasonable abatement to be approx. $1,000,000,000 for municipal sewage, $52,000,000 for coal mine drainage, $100,000,000 for treatment oil field brine, and $900,000,000 for industrial wastes; annual operating and maintenance costs would be at least $15,000,000. Two types of Federal bills introduced for solution of problem, one by setting up new, separate, federal regulatory agency acting through injunction procedures in U. S. courts (first bill—Lonergan Bill); second type providing for federal participation, through an existing agency (U. S. Pub. Health Serv.) in a program of educational research, and coordinating activities, but with regulatory control left to the states (Barkley-Vinson type). Latter favored by all public health agencies of country, all federal bureaus and depts. concerned with water quality and use, and various planning agencies. First type favored by organized wild-life conservation groups. Arguments presented on behalf of second type of bill. More progress made in municipal pollution abatement in past 6 yr. than in preceding 25, tributary pop. to sewers increased from 21.5 to 39.7 million at cost approaching 1 billion dollars. Author believes that with a

national campaign conducted under such plans and with reasonable availability of Federal funds, progress in abatement comparable to past 6 yrs. will be obtained and that within 6 to 10 yr. most objectionable sewage and waste pollution will be corrected.—*Martin E. Flentje.*

**Court Decision on Public Health.** Pub. Hlth. Rpts. **54:** 1693 (Sep. 15, '39). Liability of town for pollution of stream. (N. Carolina Supreme Court; *Clinard et ux.* v. *Town of Kernersville et al.*, 3 S.E. 2d 267; decided 6-16-39.) An action was brought against town and knitting mill to recover damages because of pollution of stream which crossed plaintiffs' land. Water from town's sewage disposal plant and water used by knitting mill in connection with dyeing process entered stream. Upon appeal, appellate court concluded in part that: damages are to be assessed as of time defendant first began to discharge into stream, water and other substance which polluted water and produced noxious and offensive odors on plaintiffs' land, upon basis of difference between fair and reasonable market value of property just before and just after defendant began to use stream, assessed upon theory that defendant at that time took and appropriated an interest in property of the plaintiffs for which it must pay. Past, present, and prospective damages are not to be considered.—*Ralph E. Noble.*

## FILTRATION

**Filter Plant Experiences.** L. R. MATHEWS. W. W. Eng. **92:** 1484 (Nov. 22, '39). The ten 2.4-m.g.d. filters of Fort Wayne, Ind. softening plant were reconditioned after 2½ yr. use. Sand size draining period had increased 11%, gravel had become cemented somewhat and filter runs had decreased from the 30 to 100 hr. ave. Sand cleaned by removal to special screen room in plant equipped with vibrating screen operating at screening rate of 3.5 tons per hr. Exptl. use of a wash water trough paint made of phenol formaldehyde vehicle and with carbon black pigment appears to have promise of success.—*Martin E. Flentje.*

**Filtered Water for Chicago.** LORAN D. GAYTON. Eng. News-Rec. **123:** 682 (Nov. 23, '39). Principal features of 320-m.g.d. filter plant that will serve 54% of area and 38% of population of city are described. Will be located on 150-acre area of land to be reclaimed from Lake Michigan between 75th and 79th streets for purpose of constructing plant, park and beach. Project includes 2 mi. of 16′ tunnel in rock in 2 sections: one section to convey raw water from Edward F. Dunne Crib to filter plant and other to carry filtered water from plant to existing tunnel system. Second raw water source is provided for in intake ports on lake side of substructure. Present work, costing $12,000,000, which will carry project as far as completion of substructure, is to be finished in June '40. Ultimate cost is estd. at $20,000,000. Plant is designed for ave. annual delivery of 225 m.g.d. and hourly peak of 450 m.g.d. At nominal rate of 125 m.g.d. (2 gal. per sq. ft. per min.), plant capacity is 320 m.g.d. Plant capacity is based on max. ave. daily filtration rate of 2.5 gal. per sq. ft. per min. in winter and 3 in summer, if acid-treated sodium silicate is used to strengthen floc. Rates may be exceeded for periods of several

hr. daily, with 3-gal. max. winter rate and 4-gal. max. summer rate. If silicate is not used, max. rate should ave. not more than 2 gal. for day and should not exceed 2.5 gal. at any time. On basis of 225-m.g.d. capacity, mixing time will be 45 min. and settling period 4 hr. There will be 80 filters, grouped in units of 20. Clear water res. will have capacity of 50 mil. gal. Four 50-m.g.d. and four 100-m.g.d. direct-connected motor-driven centrifugal pumps will be provided. Sedimentation tanks will be 32.5′ deep, with intermediate settling floor at half depth. Scrapers will drag sludge to one side, where cross collectors will convey it to sumps for continuous removal. Both water used in removing sludge and wash water will be reclaimed. Carbonation is provided for. Filter units will be 54′ × 26′ (1404 sq. ft.) and wash water troughs will be 24″ above top of sand. Perforated pipe underdrains, 4″ diam. on 12″ centers, will be shown on plans but bids will be allowed on patented filter bottoms. Surface wash system will be provided.—*R. E. Thompson.*

**Double-Deck Settling Basins.** Loran D. Gayton. Eng. News-Rec. **124**: 528 (Apr. 11, '40). Double-deck basins were adopted for Chicago filtration plant because of topographical conditions; saving effected thereby amounting to almost $250,000. Elevation of basins was fixed by head required to provide gravity flow through plant and overcome loss of head in tunnels leading to 3 pumping stations which will be served. Single-deck structures providing desired water depth of 15′ would have had to be supported on made-fill or long columns, and increased area covered would have required much larger coffer dam. Double-deck settling basins were employed at Fort Wayne, Ind., and Milwaukee, Wis., for similar reasons. Basins are operated in parallel. Ave. and min. detention periods in coagulation basins will be 58 and 35 min., respectively, and in settling basins 4 and 2½ hr., respectively. In ⅓ of length of settling basins, transverse scrapers drag sediment to one side, where cross collectors convey it to concentration sumps. Coagulation basins will be equipped with mechanical agitators on horizontal shafts, water traveling in direction of center line of agitators.—*R. E. Thompson.*

**Sacramento Filtration Plant Built in Duplicate.** Theodore Reed Kendall. Am. City, **54**: 6: 74 (June '39). Sacramento has endeavored to insure continuity of operation of its water plant by building in duplicate. From intake, two 60″ lines, later reduced to 42″ lines, convey water to pumping station. Station is so arranged that it can be divided into two complete units both electrically and hydraulically. Power comes to station from two systems. For aeration and clarification, two sections are provided in plant. One section being newer than other is operated in slightly different way. 16 filters are subject to manipulation to give flexibility. At Sacramento, alum is manufactured at plant at less cost than for commercial alum delivered there.—*Arthur P. Miller.*

**The Works of Mézières-sur-Couesnon. Water Supply of the Town of Rennes.** Anon. L'Eau (Fr.) **32**: 31 ('39). Describes water works at Mézières which supply to town of Rennes in Brittany up to 10,000 cu. m. per day to supplement a supply from springs which had become insufficient. Raw water, drawn from Couesnon R., is highly colored and contains organic matter, clay, and iron

salts. Treated with aluminum sulfate, settled, filtered, and chlorinated. Sand filters can be back-washed or cleaned by "ejection". Latter method consists in directing a stream of water under pressure into lower part of filter so that sand is drawn into hopper bottom, forced up a pipe in center of filter, and deposited on surface.—*W. P. R.*

**Historic Filtration Plant at Lawrence, Mass.** THEODORE R. KENDALL. Am. City, **55**: 2: 39 (Feb. '40). Marked advancement has always characterized water treatment methods employed by Lawrence, Mass., since installation of first slow sand filters in 1893. New 10-m.g.d. rapid sand filtration plant is equipped with surface wash for filter sand to guard against mudballs, and an interesting innovation is wash-water troughs running parallel with filter gallery, instead of perpendicular to it. In designing plant, careful thought was given to insure protection against river floods. In pumphouse motors are guarded against possible damage by arrangement whereby they can be picked up and hung from ceiling, if necessary. Pipe gallery is especially outstanding in its construction promoting max. of efficiency of operator by ready access to every control valve and pipe, by good lighting units and easy cleaning facilities. Apparatus for application of chemicals (alum, lime, activated carbon and chlorine) so designed as to permit quick change of points of application and use of any machine for any chemical.—*Arthur P. Miller.*

**Treating Lake Michigan Water at Muskegon Filtration Plant.** ANON. Am. City, **55**: 2: 56 (Feb. '40). Muskegon, Mich., pop. 47,000, demands normally only 4.5 m.g.d. but reaches requirement of 14.0 in summer. Looking ahead, City in '36 built filtration plant allowing for adequate treatment and storage for years to come. Provision for a peak capacity of 18 m.g.d. and for addition of another set of filters when required. Treatment is with alum, activated carbon and chlorine. Carbon is applied at the rate of 1 p.p.m.; chlorine at 6 lb. per mg. and alum at $\frac{3}{4}$ g.p.g. In winter alum dose is increased to $1\frac{1}{2}$ g.p.g. Treatment of the water is governed to some extent by peculiar and interesting circumstance. The 48" cast iron intake is located between Grand R. to south and Muskegon R. to north. Steady wind blowing from south causes Grand R. water to show up yellow in intake; and wind blowing from north causes Muskegon R. water to show up black. Occurs but rarely, however, and when it does an increased amount of activated carbon is applied to temper taste in water caused by wastes in two rivers. Filtration is at 125 m.g.d. Filters are operated about 30 hr. in summer and as little as 5 hr. in winter. This plant is also equipped with a lab. for making chem. and bacteriological tests.—*Arthur P. Miller.*

**Water Treatment Methods of Four Filter Plants Supplying Charleston, W. Va., and Nearby Towns.** P. L. MCLAUGHLIN. W. W. Eng. **92**: 1238 (Sep. 27, '39). Four purification plants at Charleston, Belle, Nitro and St. Albans, W. Va., supply water to 125,000 inhabitants of Charleston and neighboring Kanawha Valley communities. Plants take water from Elk, Kanawha and Coal rivers. Description of plants and operating methods given. Chem. tests made at individual plants; daily and weekly bacterial tests carried out in central lab. at Charleston.—*Martin E. Flentje.*

**Construction and Operation of Rapid Sand Filters at Lawrence, Mass.** Arthur L. Shaw and E. Sherman Chase. J. N. E. W. W. A. **53**: 412 (Dec. '39). Merrimac R. (watershed—4461 sq. mi.) water used for supply of Lawrence, Mass., originally filtered through slow sand units; first unit built in '93; this divided into 3 sections in '02; easterly section covered in '17; new covered filters added in '07 and '25; chlorination begun in '18. Typhoid death rate per 100,000 decreased from 60 in '79 and 79 in '93 to 23 in '02, 8.5 in '19, 0 in '33 to '37 inclusive, and 1.1 in '38. Untreated sewage from several cities discharged into stream above Lawrence, particularly that of Lowell (pop. 100,000) 9 mi. upstream. High coliform density reported, 16,800 per 100 ml. in '38. Abandonment of river recommended by engineers and State; however, because cost too great, double filtration installed at cost of $628,000. New plant has 10 m.g.d. capac. with 8-m.g.d. filters installed, 3 low-lift pumps of 5, 6, and 7 m.g.d. capac. respectively; dry-feed machines for alum, lime, carbon, and spare; 2 pre- and 2 post-chlorinators. Water passes through 2 mechanical mixing basins 20′ x 20′ x 18′ deep with 15 min. retention at 10 m.g.d.; 5 coagulation basins 95′ x 33′ x 14′ to 16.5′ deep with 4 hr. retention and with flocculation in first quarter of each basin; 10 filters with 18′ x 20′ x 4″ sand area (2 not equipped) and 18″ gravel from $1\frac{1}{2}''$–$2\frac{1}{2}''$ size to 12 mesh, 30″ of 0.46 mm. effective size sand. Plant has aeration, wash water pumps with capac. to provide from 24″ to 34″ wash water rise per min., and surface wash. Entire plant protected against highest flood. Plant operated since Dec. 16, '38 with from 140 to 178 lb. per m.g. alum used as mo. ave., little or no carbon, approx. 4 lb. chlorine per m.g. ave. for prechlorination and approx. 5 lb. for post-treatment. Wash water percentage varied from 1.3 to 2.5, ave. filter runs from 36 to 77 hr., out of 600 ten ml. inoculations of filtered water only 13 (2%) gave positive tests for coliform bacteria.—*Martin E. Flentje.*

**Calgon at Columbus.** Charles P. Hoover. Ohio Conf. Water Purification, 19th Ann. Rept. p. 99 ('39). Filtration of lime softened water causes sand encrustation and attendant operating difficulties. At Delaware, Ohio, alkalinity was reduced 30 p.p.m. in passing through filters and it was demonstrated that water could be stabilized and encrustation prevented by application of sodium hexametaphosphate. Reduction in hardness is lost by this method, however, and there is no known method of removing supersaturated calcium carbonate as cheaply as by passing the water through sand filters. At Columbus, 0.25 p.p.m. "Calgon" is being applied to entire softened filtered supply. There is little difference in alkalinity of water leaving the plant and that drawn from distr. system, indicating that water is stable. Lab. comparisons are being made of effect of "Calgon" and two other trade preparations, "Tetra-pyrophosphate" and "Nalco No. 18," which are claimed to prevent calcium carbonate deposition in hot water systems.—*R. E. Thompson.*

**Calgon at Kent.** O. H. Young. Ohio Conf. Water Purification, 19th Ann. Rept. p. 101 ('39). Kent plant consists of softener and three 0.5-m.g.d. pressure filters. Calcium carbonate is deposited on filter sand and in piping system and valves of plant. "Calgon," applied prior to filtration, has prevented this trouble. Hardness of treated water is about 12 p.p.m. higher since treatment has been employed.—*R. E. Thompson.*

**Gravity Filters—Underdrains.** ANON. W. W. Inf. Exch., Canadian Sect., A. W. W. A. **3**: A: 1: 1 (Jan. '40). Data concerning underdrains in 67 Canadian gravity-filter plants are tabulated under following headings: manifold size; size, spacing, and material of laterals; size, spacing, and kind of orifices. Material used for laterals in 46 plants is as follows: c.i., 29; wrought iron, 7; brass, 6; steel, 1; copper, 1; sherardized pipe, 1; c.i. and brass, 1. Size of laterals varies from $1\frac{1}{4}''$ to 4″ and spacing from 4″ to 16″ center to center. Size of orifices varies from $\frac{1}{16}''$ to $\frac{3}{4}''$ and spacing from 3″ to 12″.—*R. E. Thompson.*

**Porous Plate Filter Bottom.** HENRY T. HOTCHKISS, JR. W. W. and Sew. **86**: 442 (Nov. '39). Troubles due to gravel disruption in rapid sand filters led Larchmont, N. Y., to try a porous plate underdrain system which eliminates gravel. Cementation of gravel and underdrain corrosion were severe in former installation. Flat porous plates were installed above existing manifold to form false bottom. Plates are held by stud-bolts cemented in floor, joints between plates being sealed by hot-poured material.—*H. E. Hudson, Jr.*

**The Sterilization and Cleaning of Slow Sand Filters.** D. RONALD. Munic. Eng. Sanit. Rec. **103**: 356 ('39). Describes removal with chlorine of oxidizable matter from choked slow sand filters without removing filter medium. Sodium hypochlorite is probably most convenient form in which to apply chlorine. An ave. of about 10 gal. of a soln. containing 14% available chlorine is required per 150 cu. yds. of filtering material. Sodium hypochlorite is added to water to give a concn. of 40 p.p.m. chlorine or 280 p.p.m. sodium hypochlorite, and mixture is passed through filter. Found that if 0.2 p.p.m. chlorine is present 10 min. after hypochlorite has been added good bacterial purification is obtained. Details summarized. *Discussion.* W. DUNBAR: Said that at North Craig it had been found necessary to add chlorine as quickly as possible. Instead of applying it at inlet it was distributed over surface of filter. About 150 p.p.m. chlorine had to be added to water in filter to obtain 0.25 p.p.m. at outlet. "Hypo" should be available to neutralize chlorine if scour water contains more than 0.3 p.p.m.—*W. P. R.*

**Cleaning Sand at the Springwells Filter Plant.** R. J. LAMARRE. W. W. Eng. **92**: 1538 (Dec. 6, '39). Filter sand in first 20 filters of 272-m.g.d. capacity Springwells (Detroit) Filtration Plant began to show small mud balls throughout sand after approx. 4 yr. use. Sand also covered with about $\frac{1}{4}''$ of conventional accumulation of solids and organic matter. To clear these filters, 3 locally-made sand ejectors placed in separate sections of filter 2″ above sand surface. In cleaning, wash water turned on at rate to give 10% sand expansion (2″) which was found sufficient to bring mud balls to surface but not to fold under again. Ejectors then operated to pick up mud balls, discharging to sewer with wash water. For cleaning 1,089 sq. ft. filter, 3 mil. gal. wash water used, 50,000 gal. ejector water and 5 hr. labor at total cost of $19.50 per filter. Plans made for permanent grid installation with 16 ejectors to be used in each regular wash.—*Martin E. Flentje.*

**Filter Plant Operation Aided by Proper Lighting.** HOWARD O. HEIMAN. Am. City, **54**: 10: 47 (Oct. '39). Special attention was given to securing adequate lighting devices for Milwaukee Water Purification Plant. In washing

filters, it is important that proper observation can be had. To secure this, tests were made after which it was decided that an intensity of 20-ft.-candles was necessary on surface of water at wash troughs and that this illumination should come from widespread floodlight over operator's head and directed out over filter. In pump room, high and low intensity system of illumination employed. In pipe galleries, units having an upward illumination component of 20% were needed to shed light on upper structures. Wide-spread, low-level illumination installed in chem. and storage rooms and over service aisles between filters. In main operating aisles, large cast bronze lanterns placed on 20′ centers and 22′ high. In each case, specific type of unit used is given.—*Arthur P. Miller.*

## RATES

**Is Fair Return Appropriate for Municipal Utilities?** RODERICK H. RILEY. J. Land & Pub. Util. Econ. **16:** 52 (Feb. '40). Question of fair return for municipally owned utilities can, of course, arise as a practical matter only in those states in which municipal rate-making for such utilities is subject to review or approval by state. Ind. commission denied municipality of Logansport right to earn a fair return and right to charge rates to cover payments in lieu of taxes. State supreme court reversed commission on former point but sustained it upon latter, holding municipality acts in its private capacity in operating a utility. N. Y. Court of Appeals sustained lower courts in holding Public Service Commission without statutory authority to disregard requirement of fair return in determining municipal utility rates. Claim that a given activity or function of a municipality is in a proprietary or private capacity is generally concerned as a liability for a tort or to protect it from legislative interference. Most single significant circumstance in determining proprietary capacity in liability cases appears to be whether activity is conducted for profit. U. S. Supreme Court decisions indicate Federal Constitution does not hinder state operation of utilities. Whether this permits municipal utilities to be operated under state regulations by municipality is not clear from decisions. Recently court stated a municipality operating a utility "is exercising a part of the sovereign power of the state." Following two conclusions may be ventured: (1) In operating a utility, municipality acts in a proprietary capacity, subject to statutory limitations of state legislature which may make this a governmental function. (2) Determination of proprietary capacity relate to a municipality's liability for torts and also establish rights against other persons. Supreme Courts definition of property based on an exchange-value. This being so, to have corporate property is to concede a fair return upon it. There must be a fair return on utility investment if enterprise is to continue as going concern. If municipal utility is purely local, probably wrong to say, financing methods should not be left to municipal authorities. Proponents of municipal ownership of utilities, commonly misunderstand public economics and insist upon applying private business standards without considering their appropriateness.—*Samuel A. Evans.*

**Will Rising Production Costs Hurt Utility Investors?** FERGUS J. MCDIARMID. Pub. Util. Fort. **25:** 204 (Feb. 15, '40). Upsurge in costs in the years immediately ahead not anticipated, but, looking farther, consider how com-

panies are situated to meet a possible rise in operating costs if and when it occurs. Need for rate adjustments as nearly automatic as possible. Increasing expenses will encroach upon earnings until investor is frozen out; war in Europe has focused attention on this aspect of utility operations. Financial manual of utilities of 20 yr. ago is now antiquated; many large systems of today were only infants then. Proportion of operating revenue absorbed by operating expenses, maintenance and taxes increased approx. 25% from '14 to '20. Probably price levels of the years ahead will not follow pattern of those years. World is now divided into group of more or less economic compartments, through which price changes are transmitted slowly; credit does not flow as freely across international boundaries. Present restricted outlets of U. S. have a depressing effect on internal prices. Unbalanced state of Federal budget cause for concern, no reversal of trend of the underlying cause in sight. Rising costs and taxes will tend to whittle away earnings without effecting a show-down. What will be attitude of regulating authorities? Recent decision of Ill. Supreme Court that 5% return on property value was not confiscatory may offer clue. Slowness of machinery in rate adjustments is an investor's trial, although in N. Y. and Pa. temporary rates are allowed on short notice. If rates may be lowered, presumably on basis of equity they could be raised, similarly. At present utility investor may as well realize that there is no adequate insurance for safety of his earnings, in a period of rising costs. Remedy is an intelligent selection of utility securities best able to take it on the chin. Comparative solution of problem, amount left after paying bond interest or preferred dividends as a percentage of operating expenses including maintenance, ratio indicates probable proportionate rise in operating expenses before company ceases to earn bond interest. Owing to unbalanced Federal budget, some future inflation in prices is likely, necessary to set up machinery to make rate adjustments as nearly automatic as possible to conform with changing price and wage levels.—*Samuel A. Evans.*

**Valuation or Historical Cost: Some Recent Developments.** G. O. MAY. J. Accountancy **69:** 14 (Jan. '40). Misapprehension on part of economists, also few accountants, as to nature of balance sheet. Great value in closer mutual understanding between economists and accountants. Balance sheets not purely statements of values, but based largely on cost. Basic issue, extent to which accounting rules are deduced from broad generalizations, derived inductively from specific cases, and how far regarded as responsive to economic and social change. Committee of National Bureau of Economic Research regards corporation accounting as one phase of working of the corporate organization of business; test lies in results produced. Accounting is conventional, being required for many different purposes, therefore same conventions not appropriate for all. There is a change of emphasis from balance sheet to income account, from long time investor to one always buying and selling. Problems considered more from standpoint of current buyer or seller than from continuing owner. Corporations whose securities are listed on any exchange about 3,000 of several hundred thousand making income tax returns. Difficulties and uncertainties of accounting due to 2 different principles applied to balance sheet historical cost and valuation, and 2 principles

employed in income account: (1) accrual which involves treatment of interest, rents, taxes, and provision for depreciation, amortization, etc.; and (2) that of the completed transaction. Finally balance sheet and income account must be in conjunction. One of major problems of accountancy, to make clear why different principles are employed and when applicable. In Congressional Revenue Act of '39, "last-in, first-out" method of inventorying authorized, its great merit is flattening out of earnings curve during periods of price fluctuation; treasury regulations on this rule not yet issued. Considering method as it affects balance sheet; if last goods purchased are deemed first used or sold, figure in inventory reflects cost of earlier purchases, in time inventory reflects price level of an increasingly remote period. If good accounting principles require inventories based on prices for similar goods in past; *a fortiori* good accounting requires fixed assets carried at past paid prices for actual property. Thus adoption of "last-in, first-out" method lends strong support to using historical-cost basis for fixed properties. Balance sheets should not attempt to reflect values of fixed assets. Case for carrying fixed assets of corporations on basis of historical cost less depreciation well established, no alternative to date. Remedy, not abandonment of historical cost, but readjustment of par values and carrying figures for property, bringing both in closer relation with reality.—*Samuel A. Evans.*

**Monopoly Pricing in Shaping Utility Rate Schedules.** C. Emery Troxel. Pub. Util. Fort. **24:** 796 (Dec. 21, '39). Number of years have passed since utilities started furnishing many classes of services with appropriate rate differences. Writers on economics have frequently accepted seemingly irreconcilable conclusions that in rate making there is some of "what the traffic will bear"—a synonym for monopoly pricing—and cost studies justify differentials of class rates. Conclusions about service costs often depend on selection and arbitrary means of cost allocation. Some costs rightly associated with one type of service, but interest, depreciation and operating costs relating to several classes of service cannot always be apportioned accurately. Another cost argument, is wider spreading of fixed costs used to justify any business that increases revenue more than cost. Spreading of fixed costs usually based on assumption, no change in fixed costs, this restricts argument to existing plant, not applying to expansion. Lower rates for new business but not for old believed to be warranted, however these cost reductions would not have been within reach in absence of existing customers and sales. Price discrimination necessary for some utilities; mistake to believe monopolists always profit, railroads example of this lack of observation. Price discrimination may be means of minimizing deficits as well as maximizing profits, a condition likely when demand decreases. Many believe public utility rates have been and are determined according to what traffic will bear. Monopolist would not sell each unit at uniform price if it were possible to increase revenue and profits otherwise. Number of service classes rate schedules, limited by public opinion or difficulty of separating customers into classes. Variation in demand of classes accounts for an advantage in rate differences, variation is dissimilarity in elasticity of demand. Elasticity of demand describes change in total revenue which would accompany reductions or increases in

price; demand inelastic when total revenue from sales declines as prices are lowered. Monopolist charges higher price to customers with elastic demand, thus rates yield a larger total revenue for same expenditures than by uniform rate. After certain limit reached in sales to customers with inelastic demand, more profitable, to seek sales at lower rate in elastic demand class than to lower rates for the former class. Discriminatory pricing used to obtain more than fair return, because of infrequency of rate investigations, attributable to awkward and expensive legal requirements of regulation. Some commissioners would not recognize rate discrimination if they encountered it.—*Samuel A. Evans.*

**Temporary Rate Making Comes of Age.** IRVINE E. JACKSON, JR. Pub. Util. Fort. **24:** 723 (Dec. 7, '39). What is temporary rate making for utilities, who started it and why? A new regulatory technique installed in U. S., new as of '34, commission fixes a utility's rates tentatively on basis of preliminary property valuation. Temporary rates effective until final or more thorough determination of utility set-up, under N. Y. and Pa. versions, deficits may be recouped, if preliminary commission order erred. Temporary rate appears to be here to stay, strictly American, aftermath of '29. Transportation Act, '20, a prototype. Utility rate legislation lingering interminably in courts prominent factor in fostering temporary rate; popular merchandising power paralyzed, rate reductions for utility consumers imperative, further legalistic delay intolerable. Original cost as a basis for temporary rate investigation, here Pa. followed Calif. and Mass. commissions, approved by rate regulation students, as by former Supreme Court Justice Brandeis. Pa. statute so skillfully drawn that regulatory rate not irrevocably tied up with prudent investment doctrine. In Edison Light & Power Co. Case, U. S. Supreme Court did not present its attitude on merits of the old "prudent investment vs. 'present fair value' controversy." Court found Pa. commission could fix temporary rates upon original cost or 14 yr. old precedent in Smyth v. Ames. Mar. '38 Pa. Comm. ordered Beaver Valley Water Co. to make $29,500 temporary rate reductions. Water company in court maintained temporary rate a confiscatory charge. Federal Dist. court upheld commission; for temporary rate to be indisputably installed in regulatory jurisprudence, only U. S. Supreme Court approval required, discernible signs point to this approval. Born in a depression, temporary rate-fixing does not need an emergency to justify its invocation.—*Samuel A. Evans.*

**Temporary Rates—Good and Bad.** J. HARRY LABRUM. Pub. Util. Fort. **25:** 214 (Feb. 15, '40). To save money it is decidedly advantageous for utility executives to study trend toward temporary rates. Other states will probably follow the few and adopt temporary rate plan. This is important in planning long term capitalization or mergers. Two arguments advanced by proponents of temporary rates; first existing rates too high, second lower rates would bring increased consumption without reduction in total revenues. Right to impose temporary rates cannot be doubted. N. Y. Supreme Court held where rates not legislated for a definite period they should be enjoined. In Pa. a statutory court determined that a commission order fixing temporary rates was not a

final legislative act, not confiscating property in a permanent sense, as water company could recoup losses through a temporary increase if final prescribed rates proved to be higher than temporary rates. No limitations on duration or amount of temporary rates if recoupment was afforded. Regulatory commissions should be fair in their administration of temporary rates if they are to offer a solution for the problem of rate regulation. They should give careful consideration to established law in applying temporary rates, and temper their political views with a facing of facts in the record. In few states having temporary rate making not enough thought has been given to mechanics by which a utility may recoup any taking of its property by a non-compensatory temporary rate. Legislature can abolish a law enacted leaving utility powerless to collect losses. In some states, e.g. Pa. temporary rates not on a uniform basis, may be confiscatory even with recoupment. Pa. statute allows 5% on physical property only. Exclusion of indirect costs in reaching a rate base new in valuation proceedings. Idea of temporary rates appears good, probably a better solution than prudent investment theory. Where temporary rate is compensatory, utility will save a great deal of money in useless litigation, engineering, and accounting studies. Temporary rates at least offer a new approach and partial solution of difficult problem. If properly administered, they would speed up process of rate making and eliminate much useless effort and expenditure on part of both the regulatory commissions and the utilities.—*Samuel A. Evans.*

**Beaver Valley Water Co. v. Denis J. Dricoll et al. Decision U. S. District Court. W. D. Pennsylvania.** Pub. Util. Fort. (Dec. 7, '39), P.U.R. **30**: 305. Injunction suit to restrain enforcement of State Com. order temporarily reducing water rates; temporary injunction dissolved and bill of complaint dismissed. Com. initiated inquiry and investigation resulting, in order requiring temporary rate reduction amounting to $29,500 in annual gross revenue. No oral argument or briefs filed with Com. Water company claimed ruling unconstitutional, violating Fourteenth Amendment. Question, whether temporary rate constitutional, if although based solely on depreciated original cost, there is statutory provision for recoupment by utility company if temporary rate is finally determined not to provide fair return, this is issue before the court. Com. fixed temporary rates upon basis of original cost less accrued depreciation, as statute required, allowing 1% more than statutory minimum. Due process clause fully available to company in proceedings to determine final rates. Therefore temporary rate not unconstitutional, since there exists statutory provisions for recoupment of losses suffered by water company, due to temporary losses.—*Samuel A. Evans.*

**Borough of Ambridge v. Pennsylvania Public Utility Commission, Before Pennsylvania Superior Court.** Court Ruling. Pub. Util. Fort. (Jan. 4, '40), P. U. R. **31**: 50. Appeal by borough from Commission order fixing municipal plant rates for water service outside of borough; reversed, and complaint by customer dismissed. Vital question whether borough supplying water to its own inhabitants from own plant, also furnishing water outside borough (1) may establish a different rate schedule for consumers outside borough, or (2)

may be required by Public Utility Com. to treat outside customers as if whole plant were a private water company, and no segregation of customers for rate making purposes. Borough takes first position, com. and outside consumers second; court concurs in borough's contention. Public Service Company Act of 1913 gave com. no power of supervision or regulation over rates charged by a municipal corporation which furnished water or other public service to its inhabitants or to customers residing outside its limits. But the Public Utility Law of May 28, 1937 stated "that any public utility service being furnished or rendered by a municipal corporation beyond its corporate limits shall be subject to regulation and control by the com. as to rates, with the same force, and in like manner, as if such service were rendered by a public utility." The com. used this section of the act to base its contention as to schedule of rates outside a borough, but treated the whole as one operating private utility. This overlooks the provision giving the com. *any* authority, restricts it to any public utility service ***beyond its corporate limits.*** Com.'s contention if sustained would give it authority to determine rates within the borough, but it could not enforce them. Court rules statute does not give com. either authority, but only to regulate and control rates beyond borough limits, fair and reasonable rates based on fair value of property used, with just allocation, of plant investment within borough and of operating, maintainance, and depreciation charges. Com. ignored use of facilities and allocated on an arbitrary basis. A third class city fixed rate schedules for consumers inside the city and a higher rate for those outside city. Present Chief Justice laid down following principles: (1) rates of a municipally owned water company are controlled by the courts and not by Public Utility or Service Commissions; (2) applicable to rates outside the city controlled by Public Utility Com., law requiring fair value standard; (3) courts or legislature cannot prohibit a municipal water plant from making a fair return by way of profit on furnishing water; (4) determinarion of fair value of a municipal water system must be made in the same manner as private utility corporations; (5) fair value of plant for rate fixing within city must have plant fair value for outside city deducted; (6) cost of operating plant with all expenses must be proportioned for outside service; (7) city may charge more for water outside its limits – citizens cannot be asked to pay expenses incurred in supplying water outside the city.—*Samuel A. Evans.*

**Borough of Auburn v. Auburn Water Co. Pennsylvania Public Utility Commission.** Ruling. Pub. Util. Fort. (Jan. 4, '40), P. U. R. **31**: 56. Borough of Auburn complainant, contended franchise provided water company install fire hydrants, city pay $14 annually for first 20, $5 for each additional until such time as revenues equal interest upon cost of plant, then water furnished free to all fire hydrants. Borough maintained after furnishing free water service from '06 to '38, respondent filed a tariff charging $25 annually for each fire hydrant, which is excessive and unwarranted. Respondent maintained free water service cannot be rendered to consumers, even a municipality, and burden of proof in an attack on rates rests with complainant. Three questions involved: (1) whether discriminatory for a public utility to furnish public free fire hydrant service; (2) whether a hearing or not on complaint; (3)

whether or not in a complaint proceeding against the unjustness and unreasonableness of an existing rate of a public utility, burden of proof upon complainant. Public utility law provides utility must adhere to tariffs; in all cases, there must not be any discrimination in any way whatsoever. Hearing granted, complainant may present case. Burden of proof, as to excessive and unjust fire hydrant service rates, upon Borough of Auburn.—*Samuel A. Evans.*

**New Jersey Suburban Water Company v. Board of Public Utility Commissioners et al.** (New Jersey Court of Errors and Appeals Ruling.) Pub. Util. Fort. (Feb. 15, '40) P. U. R. **31**: 219. Water Company had a 15-year contract, with 10-year option, to sell water to town of Harrison. During option period exercised by Water Company, it petitioned Board of Utility Commissioners for rate increase, board fixed a rate, which was confirmed by N. J. Supreme Court. Two questions: Did Supreme Court erroneously exercise supervisory power? Is fixed rate reasonable? Supreme Court decision reviewed on merits, unwise for Error and Appeals Court to determine status of rate, where it is questionable whether the Supreme Court made same factual finding as Commission. Reproduction cost is a factor in determining fair value for rate making purposes. Value of water company's plant depends upon use and profitableness of present and prospective services rendered. If a main used is twice necessary size, and water company is obligated to use same, it is entitled only to a fair return upon fair valuation of that main. Depreciation starts on a water plant and additions from moment of use. Testimony of competent valuation engineers preferable to mere calculation based on averages and probabilities for rate making purposes. Taxes on property other than that useful to public should not be allowed as operating expenses. Under all circumstances a water company is only entitled to compensation for service rendered. Rate return of 6¾% was sustained as fair and just in reviewing a commission order. Commission justified in considering comparative rates in similar localities when fixing rates.—*Samuel A. Evans.*

## Erratum

On page 943 of the June, 1940, issue of the JOURNAL the word "*thousand*" should be substituted for "*million*" in the item now reading "Ave. revenue *per million cu. ft.*"